The Foundry Trade Journal

AND PATTERN-MAKER.

THE OFFICIAL ORGAN OF THE BRITISH FOUNDRYMEN'S ASSOCIATION.

Vol. 13. **SEPTEMBER, 1911.** **No. 117.**

PUBLISHED THE FIRST WEEK IN EACH MONTH

Subscription Terms: 7s. 6d. per annum, post free.

To place the "JOURNAL" within the reach of Working Moulders and Pattern-makers the Proprietors will accept subscriptions, not less than three in number from one shop at the reduced rate of 5s. per annum, such order to be countersigned by the superintendent or foreman.

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THE FOUNDRY TRADE JOURNAL,
165, Strand, London, W.C.

WE INVITE PRACTICAL ARTICLES ON THE TRADE IN ALL ITS BRANCHES, WHICH WILL BE PAID FOR. MSS. SHOULD BE WRITTEN ON ONE SIDE OF THE PAPER ONLY.

BRITISH FOUNDRYMEN'S ASSOCIATION.

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Contents.

	PAGE
Notes and Comments	505
British Foundrymen's Association—	
Eighth Annual Convention at Glasgow	507
Presidential Address	510
Discussion on Papers	511
Visits to Works	517
Papers—	
Carbon Control in Cast Iron	520
Warping in Castings of a Channel Section	523
Metallography as an Aid to the Iron-Founder	525
The Crystallisation of Cast Metals	530
Notes on the Treatment of Steel Catsings	531
Special Foundry Pig-Iron	533
Art as Expressed in Castings	534
Queries	539
Small Cupola Furnace for Cast Iron	539
Foundry Plant and Equipment—	
The "Perkins" Pattern-Maker's Bench	540
The "Stereo" Pyrometer	540
Wyllie's Riddles	541
Swinging Sand-Sifter	541
Inventions	542
Trade Talk	543
New Companies	546
Personal	548
Deaths	548
Prices of Metals	550
Parliamentary Note	550

NOTES AND COMMENTS.

The Foundrymen's Field Day.

Last month witnessed the Annual Convention of the British Foundryman's Association, as recorded on another page. The gathering was held this year at Glasgow, one of our greatest foundry centres and now a stronghold of the Association, and although the exigencies of industry did not allow many Glasgow members to be present at the business meetings, there was generally expressed a sense of satisfaction at the success of the various functions embodied in the programme. It is somewhat unfortunate that August Bank-holiday week, the usual date selected for the Convention, should be a business week for Glasgow, for it robs the occasion of much of its pleasure to find the Scottish members practically precluded from attending. But there is no doubt that the meeting did something further to advance the interests of the Association and its objects beyond the Tweed. On reviewing the Papers and discussions presented at the meetings, we must express some sense of disappointment, for they cannot honestly be said to come up to the standard of some previous meetings. Taken individually, we are not inclined to criticise the Papers themselves, for they embody valuable material; but the quantity is meagre for such an occasion, and the discussions that followed were not of that intimately practical and useful nature that one might be led to expect. In fact, some of the past session's Branch meetings have been far superior in that respect. There appears to be a disinclination on the part of our practical men to take active part in the Convention proceedings, although they are not so backward at the local gatherings. The absence of important discussion on Professor Campion's Paper, "Notes on the Treatment of Steel Castings," is worthy of remark, as it indicates the attitude of the "steel men" to publicity in connection with their work. We find a better example set in America, where several prominent steel founders have come forward with information and descriptions of plant.

It is, perhaps, inevitable that Conventions of this nature should tend to become rather social functions than earnest business meetings, for that tendency has been evinced by other and older bodies than the British Foundrymen's Association. But, after all, the Convention is the "review" day of the year, and it fulfils the function of engendering a sense of unity and fellowship amongst the members of different districts. We must, essentially, look for the Branch meetings to do the spade work of education, and it must be confessed they do it very well and earnestly. At the same time it would create a better impression in outside circles if the endeavours of the Association's officers to make the Annual Convention a big thing were more heartily responded to. Members may not realise the amount of labour en-

tailed in organising the functions of the Association, but they should appreciate the fact that it is the duty of each individual member to support, if possible, those who hold the reins. It must also be remembered that the foundry trade estimates the value of the Association in the light of what its big occasions produce, and therefore the standard of such meetings should be maintained at the highest possible point.

Art in Castings.

An interesting feature was introduced by Mr. W. F. Bagnall, who gave a profusely illustrated address on "Art as Expressed in Castings." It is as well to bear in mind that the artistic side of foundry work is not to be neglected, for the status of the trade amongst its fellow crafts is largely dependent upon its artistic as well as upon its utilitarian side. There is, however, one feature of this case which has at times been ignored. It is not for the good of the founders' craft to make it merely a means of copying work that is as efficiently and often better produced in other materials. For example, as pointed out by one speaker at the meeting, many designs are simply imitations of work which was originally in wrought iron, and which strictly belongs to that field. Cast-iron is out of place in such cases, for it does not give the strength which its formation suggests, and it does not represent the class of skill with which the design is associated. The field for cast metals might well cover the majority of work which was originally executed in stone and marble, for it is closely allied to it in its first essential—the moulding or pattern-forming operation. It further gives greater strength, and is thus quite legitimately employed. It does not detract from the dignity of the trade to acknowledge its limitations, and neither does it lower its status to acknowledge its material in the design and style of work produced, particularly when that material has a field of application which cannot be encroached upon by other arts, as is the case with founding.

Locomotive Cylinders.

At the annual meeting of the American Society for Testing Materials, held at Atlantic City, U.S.A., recently, among a number of proposed standard specifications submitted for consideration was one on locomotive cylinders, as follows:—

PROPOSED REVISED STANDARD SPECIFICATION FOR LOCOMOTIVE CYLINDERS.

(1).—Locomotive cylinders shall be made from good quality, close-grained grey iron, cast in a dry mould.

(2).—Drillings taken from test pieces as hereafter mentioned shall conform to the following limits in chemical composition:—

	Per cent.
Phosphorus	Not over 0·90
Sulphur	Not over 0·10

In case of rejection on this analysis, the manufacturer shall have the option of analysing drillings from the bore of the cylinder, upon which analysis the acceptance or rejection of the cylinder shall be based.

(3).—At the option of the purchaser, two test bars, each 1¼ inches in diameter and about 14 inches long, may be cast for each cylinder. When placed horizontally upon supports 12 inches apart and tested under a centrally applied load, these test bars shall show an average transverse strength of not less than 3,000 lbs., and an average deflection not less than 0.09 in.

The above test pieces shall be cast on end in dry sand, the metal being taken from the ladle before pouring into the cylinder mould. Before pouring, a sample of the iron shall be taken from the ladle and chilled in a cast-iron mould. The sample shall be allowed to cool in the mould until it is dark red, or almost black, when it shall be knocked out and quenched in water. The sample, on being broken, must show a close-grained, well mottled grey iron, with a well-defined border of white iron at the bottom of the fracture.

(4).—Castings shall be smooth, well cleaned, free from blow holes, shrinkage cracks, or other defects sufficiently extensive to impair the value of the casting, and must finish to blue-print size.

(5).—Each cylinder shall have cast on each side of the saddle the manufacturer's mark, serial number, date made, and mark showing order number.

(6).—The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy himself that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of the manufacturer.

Manganese Bronze.

The following is the proposed specification for manganese bronze submitted at the same meeting of the American Society for Testing Materials:—

PROPOSED STANDARD SPECIFICATION FOR MANGANESE BRONZE INGOTS.

(1).—This specification is intended to cover manganese bronze ingots, having notched flat bottoms, approximately 3 by 2¾ inches wide by 12 inches long, properly tapered to strip easily from an iron mould. Chemical composition:—

	Per cent.
Copper...	55 to 60
Zinc	39 to 45
Tin, not over	2
Aluminium, not over	0·5
Manganese, not over	0.5
Iron, not over	2

(2).—The ultimate tensile strength shall be not less than 70,000 lbs. per square inch. The elongation in two inches shall be not less than 20 per cent.

(3).—A standard turned test specimen, 0.5 inch in diameter and two inches gauge length, shall be used to determine the physical properties as specified above.

(4).—One test ingot shall be selected by the inspector to represent 10,000 lbs. of ingots or fraction thereof. The test specimen shall be cut from one corner near the bottom of the ingot. In case the test specimen shows a flaw, two additional test may be selected by the inspector from the same lot, and tested to represent the lot in question.

(5).—Each furnace charge shall be kept separate until the lot is sampled by the inspector, and each ingot thereof stamped with its proper heat number. When the ingot is sampled at destination, various heats can be mixed in shipment, but must be stamped with their proper heat number.

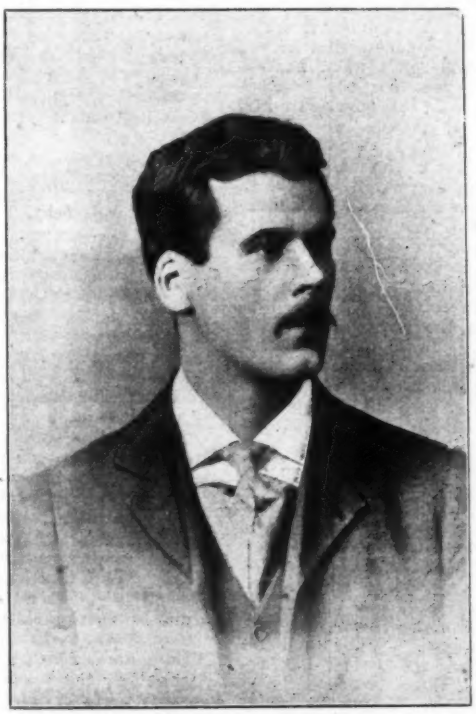
(6).—All ingots in each lot will be accepted or rejected upon the physical tests irrespective of the heat or heats from which the test ingots are selected.

In case the buyer's tests show the material does not meet these specifications, the sellers shall have an opportunity to inspect the material, and each party shall select a sample for retest. If the results do not agree, each shall select a sample to be sent to a mutually agreeable umpire, whose decision shall be final. The costs of such retest shall be paid by the loser.

British Foundrymen's Association.

Eighth Annual Convention at Glasgow.

The eighth annual Convention of members of the British Foundrymen's Association was held at the Glasgow and West of Scotland Technical College, Glasgow, on Tuesday, and Wednesday, August 8 and 9, under the presidency of Mr. Percy Longmuir, B.Met. (Sheffield). The function was in every respect successful, and has since been the subject of general congratulations, especially among the Scotch members, on whose initiative Glasgow was chosen as the rendezvous. Scotchmen are proud of the fact that they have now one of the largest sections of the Association, and, since the gathering it has been confidently predicted that a great impetus will be experienced by the local Branch as the result of the meeting. Especial satisfaction has been expressed at the immense success attending the reception by the Lord Provost at the Council Buildings. His Lordship was a peculiarly acceptable host, beacuse of his personal association with the foundry trade. Probably, the reception comprised the largest body of foundrymen and their lady friends ever got together in Glasgow.



MR. PERCY LONGMUIR, B.MET.
President of the British Foundrymen's Association.

The arrangements for the Conference were in the hands of the Reception Committee, of which Ex-Bailie J. King (the President of the Scottish Branch) was Chairman, and Messrs. W. Mayer and J. M. Riddel and Professor Campion (Vice-Presidents) were included. The following comprised the Scotch Reception Committee:—P. N. Cunningham and T. B. Rogerson (Past Presidents of West of Scotland Iron and Steel Institute), W. Macfarlane (Messrs. W. Macfarlane & Company, Saracen Foundry), A. W. Steven (McDowall, Stevens & Company), B. Doulton (Doulton & Company), R. B. Main (R. & A. Main), P. Denny (Hardy, Gordon & Denny Company), W. Weir (J. & G. Weir), W. C. Watkin, D. Landale, W. Evans, L. P. Mackenzie, T. Potter, A. McGregor, J. Meek, A. Watson, H. Phillips, J. Galt, A. Sixsmith, J. A. Ewen (Hon. Secretary). The headquarters of the Convention were located at the Windsor Hotel.

In addition to the President, there were present Messrs. F. J. Cook (Birmingham), R. Buchanan, F.R.S.A. (Birmingham), and H. Pilkington, M.I.C.E., M.I.M.E. (Chesterfield), Past Presidents; C. Jones (Cardiff), R. W. Kenyon (Accrington), Vice-Presidents, and the following members of the Council:—W. F. Bagnall (Sheffield), S. A. Gimson (Leicester), C. Heggie (Birmingham), G. B. Henderson (Southampton), T. Macfarlane (Shropshire), W. H. Sherburn (Warrington), J. Oswald (London), the Secretary, J. E. H. Allbut (Manchester), Professor Campion (Glasgow), Dr. Desch (Glasgow). The following members also attended:—J. Cook, R. C. Waddell, J. S. Glyn Primrose (Glasgow Technical College), Harry S. Primrose, M. Riddel, J. J. McCall, W. Henderson, W. Steven, A. Smith, W. B. Smith, A. A. Smith, J. Cook, J. Ewen (Secretary of the local Branch), R. R. McGowan, J Dorsie and J. Macfarlane (Glasgow), W. L. Drain, W. H. Jacques, D. Fox-Allin, H. Winterton (Birmingham), H. S. Green, Charles McQueen, J. Campbell and — Gardener (London), M. E. Edgcombe (Bengal), H. Walker, W. Russell, and H. Sherburn (Warrington), W. Evans and R. Kidston (Falkirk), A. Rankin (Alexandria), A. Harrison, — Stevenson, and J. C. C. Logan (Castleton), T. W. Millington (Sheffield), J. Oughton (Bathgate), J. Meek (Dundee), McPhee (Luton), W. Roxburgh (Kilmarnock), M. B. Newman (Preston), J. G. Cunningham and D. Wallace (Bedford), J. Teasey (Lincoln), T. Bell, George Mackay and R. M. Campbell (Paisley), W. Mayer (Dumbarton), H. P. Mason (Oldham), Horne (Erith), F. T. Cree (Durnsley), D. Dalrymple (West Bromwich), W Barmingham and A. L. Curtis (Manchester), J. G. Dobson (Derby), H. Jewson (Dereham), G. M. Mather (Ashford), B. Sperring (Portsmouth), W. E. Noon and A. Edwards (Halifax), J. Chadwick Bolton), T. Carrick (Bradford), W. Smalley (Castleton), G. Lewis (Wolverhampton).

Welcome to the Delegates.

BAILIE RUSSELL offered the visitors a welcome on behalf of the city, and apologised for the absence of the Lord Provost, who hoped, however, to have the pleasure of offering a general welcome at the Reception in the City Chambers, Municipal Buildings, on the following evening. They recognised that the foundry industry was a very important one, and

considering that Scotland, and especially Glasgow, was pretty well the home of the foundry business, their visit to the city was all the more appropriate.

MR. MACDONALD said it was his pleasure to welcome the foundrymen to the College on behalf of the Governors of that technical institution. He thought they would find the place a very comfortable one. At all events, they, as governors, spent a good deal of money in trying to make that institution almost, if not quite, the best in the world. He remarked on the fact that the growth of the Foundrymen's Association was pretty nearly coincident with that of the building. On the occasion of the holding of their Convention in Glasgow six years ago they met in the first section of the building which had been completed. At that time, the Association's membership, he believed, was something like 121, but it had since grown something like sevenfold, and so, he believed, had that building. They were very proud to remember that the foundrymen's was the first technical society that ever met in the building for the purpose of technical study.

The dual welcome was acknowledged by EX-BAILIE J. KING (Chairman of the Reception Committee and President of the Scottish Branch). In the name of the foundrymen, he assured the speakers that he was voicing the feelings of his colleagues when he told them how grateful they all were for the gracious words of welcome to the city of Glasgow. To Mr. Macdonald and the governors of the College they were also deeply indebted. It was really a great matter to be in the correct atmosphere for the discussion of any subject, and in that room they felt they were in the correct atmosphere. Mr. Macdonald had mentioned the introduction of the furnace for the equipment of the iron and metallurgical section of the Chemistry Department, and in visiting those departments they would remember that Mr. Riddel had taken an important share in initiating that equipment, and they would have the advantage of his explanation of the details. Last, but not least, on behalf of the Scottish Branch of the British Foundrymen's Association, it was his duty to give the foundrymen from other parts of the country a cordial welcome to the City of Glasgow. It was not his business to do more than offer a word of welcome, and although it was impossible for a large number of the members of the Scottish Branch to be present with them, he was authorised on their behalf to give the visitors a very warm welcome to the city. They must remember that in Scotland they were not celebrating a holiday such as was being enjoyed in the South at the present time. The Scotch holidays were just past. They were glad to welcome their English brethren and also the Scottish-English brethren—(laughter)—in Glasgow. They well recognised that ironfounding in the South had received a great stimulus from those Scotchmen who had left their country for their country's good. (Laughter.) In now inviting President Longmuir to take the chair, he could only hope that the Convention would be second to none in its success.

Mr. Percy Longmuir having then taken the chair,

The SECRETARY read several apologies. Professor Turner wrote from the University of Birmingham:—"I am sorry I shall not be able to attend the Annual Convention at Glasgow. I shall be away, and just in the middle of my holidays. Otherwise I should have been glad to have supported you in your presidency. I am glad to see you have so excellent a programme, and hope the meeting may be in every way a success." Apologies were also received from Mr. R. Mason, who was suffering from an attack of influenza; also from Mr. F. W. Finch and Mr. Penlington, the former suffering from illness, and the latter having illness at home.

The PRESIDENT suggested that they might send a telegram of sympathy to Mr. Mason, whose absence was entirely due to illness. That was the first Convention Mr. Mason had missed, and he knew that he felt very keenly his inability to be present. Mr. Finch was also away through illness, and a telegram might also be sent to him. This was agreed to by the Conference.

Annual Report.

MR. H. JEWSON (Dereham) proposed the acceptance of the annual report, which was seconded and carried. The report was as follows:—

The Council have pleasure in presenting to the members the following report of the progress and work of the Association during the past year.

Six Council meetings have been held during the year, and members have attended from Accrington, Birmingham, Cardiff, Chesterfield, Gloucester, Horsehay, Shropshire, London, Leicester, Sheffield, Southampton, and Warrington, and matters of importance to the Association have been thoroughly discussed.

The Council have pleasure in submitting to members the following suggestions for formulating a prize scheme for members of the Association for the best Paper given at the Branch meetings. They suggest that a prize consisting of a framed diploma suitably inscribed be allotted to each Branch, to be awarded to the member or associate member giving the best Paper during the session, providing that the Paper is considered by the Committee to be worthy of same. The Awards Committee will consist of the President (or failing him a member of the Council) of each Branch, and the Literary Committee of the Council of the Association. This Committee will draw up rules, etc., for working the scheme.

The Council have in contemplation an award for the best Paper of the year, this award to be applicable to the Association as a whole and to carry with it high distinction and honour to the recipient in the foundry world. The Council believe that such a scheme would act as an incentive to members and would thereby tend to draw Papers of an eminently practical character.

The Birmingham Branch Secretary, Mr. George Hailstone, has been awarded a Carnegie Research Scholarship, value £100, and is now investigating "Liquid Contraction in Cast Iron." The late Sheffield Branch Secretary, Mr. T. Swinden, has been awarded a further grant of £50 as a Carnegie Research Scholar, and is continuing his work on molybdenum steels. The Council have been successful in inducing Councils of technical schools to include in their programmes special classes for foundry employés, and classes have been formed at Halifax, Leeds, and Birmingham, which have been a pronounced success, particularly the Birmingham one, under Mr. Hiorns, honorary life member of the Association and late President of the Birmingham Branch.

The number on the roll of the Association at the present time is 674, consisting of seven honorary life members, four life members, 135 members, 382 associate members, 146 associates, compared with a total number of 571 for the year 1910. The Council regret that during the year they have lost one of their number through the death of Mr. Morris, of Butterley Iron Works, Derby, and 19 members, 22 associate members, 17 associates, have resigned or ceased to be members, and 34 members, 83 associate members, 43 associates have been elected.

The accounts for the year ending December 31, 1910, are now submitted, having been duly certified by Messrs. R. W. Kemlo and G. Hailstone, the auditors appointed. The total revenue for the year was £335 8s. 2d., while the expenditure was

£285 9s. 10d., leaving a balance of revenue over expenditure of £49 18s. 4d. This, with a balance of £52 2s. 4½d. brought forward from the year 1909, leaves a balance in hand of £102 0s. 8½d.

A new Branch has been formed in London. The first meeting was held in the Lecture Hall of the Institution of Mechanical Engineers, St. James Park, London, at which the President, Mr. Longmuir, presided, supported by Mr. Buchanan and Mr. Pilkington, Past-Presidents of the Association, Messrs. J. Oswald, S. A. Gimson, J. Ellis, members of the Council, J. E. H. Allbut, Secretary, Messrs. J. W. Horne, T. Murphy, and fifty others. The Council are looking forward to the London Branch becoming a strong and influential one, adding considerably to the status of the Association. The Scottish Branch, which was formed last year, has done exceptionally well, much enthusiasm being shown in the Glasgow district. The Papers given during the session have been highly appreciated and the meetings well attended.

The Council desire to thank the proprietors for their kindness in allowing these visits, also the gentlemen who have kindly given Papers during the session.

Six members of the Council are retiring, but are eligible for re-election. In addition to the six retiring members, three more have to be elected to take the place of the late Council member, Mr. W. J. Morris, of Butterley, whose death occurred recently, and Messrs. S. A. Gimson and J. Oswald, who have become ex-officio members of the Council, owing to their position as Vice-President of the Association and President of the London Branch respectively.

At the request of the members, the annual meeting was held in Manchester on August 2, 3, and 4. Eight Papers were read and discussed. Visits to the Locomotive Works of the Lancashire and Yorkshire Railway Company, at Horwich, and Messrs. Tweedale & Smalleys, Castleton, were highly appreciated by the members, and the picnic to Chester and Eaton Hall was a great success, the members having a very enjoyable time. The attendance at the meeting was 96, and several visitors.

British Foundrymen's Association—Seventh Annual Balance Sheet.

INCOME.

January 1st to December 31st, 1910.

	£	s.	d.
Balance from 1909	52	4	2½
Bank Interest	0	10	8
Arrears Subscriptions, 1909—			
3 at 7s. 6., 1 at 10s. 6d., 45 at 3s.	8	8	0
Subscriptions, 1910—			
3 Life Members...	15	15	0
118 Members	123	18	0
301 Associate Members	158	0	6
39 Associate Members at 7s. 6d.	10	17	6
116 Associates	17	8	0
3 Books at 3s. 6d. each	0	10	6
	£387	12	4½

EXPENDITURE.

January 1st to December 31st, 1910.

	£	s.	d.
Postage	17	19	6½
Printing and Stationery	30	11	0
Council Expenses	6	8	6
Branch Expenses, Birmingham	14	0	0
Manchester	6	19	3½
Sheffield	9	17	7½
Scottish	27	2	0
Expenses, Annual Meeting	11	14	11½
Illuminated Address for Mr. Finch	4	14	6
Printing Proceedings and Author's copies	62	7	0
Arrears Subscriptions—			
Members, 13 at 21s.: Associate Members, 71 at 10s. 6d.; Associates, 56 at 3s.	59	6	6
Cheque Book	0	2	6
Annual Audit, 1909	0	12	9
Honorarium, Secretary	30	0	0
Secretary's Expenses	3	15	6
Balance in Bank	96	3	1½
Balance in hands of Treasurer	0	0	6½
Secretary, Manchester Branch	4	10	4½
Secretary, Sheffield Branch	0	4	8
Secretary, Scottish Branch	1	2	0
	£387	12	4½

The PRESIDENT declared the various offices vacant and announced also that a proportion of the Council required to be elected.

MR. W. MAYER (Dumbarton) (Vice-President of the Scottish Branch) proposed the re-election of Mr. Longmuir as President, remarking that such re-election would afford especial satisfaction to the original members. They all knew how earnest and enthusiastic he had been.

MR. C. JONES (Cardiff) (Vice-President) seconded, and EX-BAILIE J. KING supported, and Mr. Longmuir was elected with acclamation.

The PRESIDENT, in replying, said that a year ago he intimated that he would prefer to retain office for one year only, and that was still his feeling, but the kind pressure of the Council, strongly supported by Mr. Jones, had led him to change his mind. He thanked them very heartily for their good wishes, and promised to do his best for the Association. He desired very earnestly that the B.F.A. might become a living force. He was convinced that the Papers and the general work done had improved very considerably. There was still room for a considerable amount of work in the direction of the Papers, but it was a great pleasure to see the increasingly practical nature of the Papers contributed. He hoped that the general body of members would share in the forward movement. (Applause.)

The PRESIDENT proposed the re-election of Mr. C. Jones (of Ninian Foundry, Cardiff) as Senior Vice-President. He remarked that he would rather have proposed him as President. Mr. Jones had never missed a Council meeting, but travelled from Cardiff to Birmingham, entailing a considerable expenditure of time and money. He gave his services very freely to the Association.

MR. R. BUCHANAN (Birmingham) seconded, and MR. JONES acknowledged his election.

MR. F. J. COOK (Birmingham) proposed as Junior Vice-President Mr. S. A. Gimson (Leicester), who, he said, possessed special business qualifications for the post. This was seconded by MR. C. HEGGIE (Birmingham) and carried.

The honour was briefly acknowledged by MR. GIMSON.

Mr. F. W. Finch was re-elected Treasurer on the proposition of MR. R. BUCHANAN, and the PRESIDENT then proposed the re-election of Mr. Allbut as Secretary, and said they had found him a most worthy Secretary. He had also pleasure in proposing that they again pay Mr. Allbut as a trifling acknowledgment the sum of £30. They hoped some day to be able to pay properly for services rendered.

MR. GIMSON (Leicester) seconded, and the election was carried through with acclamation,

MR. ALLBUT, in promising to do his best for the Association, expressed his great satisfaction at the growth in numbers, remarking that he hoped that soon the membership would reach four figures. They had now succeeded in surpassing the membership of the American Foundrymen's Association.

At a somewhat later stage in the proceedings the result of the ballot for the election of Council members was announced, the following being declared elected:—Messrs. W. F. Bagnall (Sheffield), J. Ellis (Southampton), C. Heggie (Birmingham), G. Hailstone (Birmingham), H. Jewson (Dereham), R. W. Kenyon (Accrington), H. Pemberton (Derby), M. Riddel (Glasgow), T. Swinden (Sheffield). Of the above list Messrs. Bagnall, Ellis, Heggie, and Kenyon are retiring members. The unsuccessful candidates were Messrs. J. W. Horne (Erith), E. Morehead (Tynemouth), W. E. Noon (Halifax), J. Robinson (Halifax), and H. Sherburn (Warrington). Mr. Morehead was a retiring member of Council.

Presidential Address.

MR. LONGMUIR proceeded to deliver his Presidential address as follows:

When addressing you last year some aspects of industrial life were dwelt on, and a few references were made to the relations of industry and science. In speaking as your President for the second year, it seems advisable to give further consideration to these matters. The field is extensive, but, on this occasion, only one or two aspects will be examined, and within short limits a few thoughts of interest to this Association will be developed.

The industrial spirit began to assume prominence early in the 14th century, and, in spite of opposition, it has expanded through the ages, and is, to-day, one of the predominant factors in life. The science of industry is a study to which each one of us must give of his best, taking all that can be gained from the traditions of the past, all that current experience can offer, and applying these to future work with a view to future progress.

The industrial character is generally regarded as eminently practical. The habit of mind induced is said to be that of leading men to think little about principles and much about results. Results are, of course, the final court of appeal, and if the verdict be satisfactory, then, to a limited extent, principles are of no immediate concern. It is only to a very limited extent, however, that principles can be ignored, as successful results can only be achieved regularly when the underlying principles governing the results are understood and realised. Consequently, although the industrial mind may be a practical one, the habit of thought now induced is such as to attach as much importance to principles as to results. In the absence of a knowledge of principles, the incentive is to commence a search for information, and this pursuit of knowledge, if diligently followed, is just as much research as that done in well-equipped laboratories and issued to the world in the form of scientific publications. Research is open to the practical man, and even he has an interest in finding governing principles, or, in other words, the reason why a certain result is obtained. Mere talk will achieve nothing. Work alone will tell, and research is absolutely essential if facts are to be discovered. Diligent work, coupled with keen observation, will materially assist the individual, the industry and the country. There is not an establishment in this country to-day in a position to say that its knowledge of the processes followed is complete, and consequently there is not one that can really afford to neglect current studies and research. The future, therefore, may be said to lie not so much in the lap of the gods as in scientific research.

In the foundry world many papers are written, but very little definite study is published. The field for work is large, and work, not writing only, is wanted. The expression of mere opinion unsupported by facts or observation, is too prevalent, and it is the duty of earnest students to encourage the publication only of that which carries the impress of work done or of observations carefully made. It matters not how much one may differ from the conclusions arrived at (differences of opinion have really great educational advantages) but provided the matter submitted represents work and thought, it demands study and respect.

There is nothing new in drawing attention to the importance of a study of the avocations of daily industry, for, after all, this simply means the acquirement of knowledge, and if history teaches anything, it shows that the love of wealth and the love of knowledge have been the two chief agents of human progress.

As a technical Association, we, of course, belong to the class which devotes itself to the acquirement of knowledge. The two pursuits generally rise together, and while the majority desire wealth, the minority desire knowledge. This may be viewed from the point of view of a Continent, a town, a small village or a works. Taking the larger outlook first, while the desires for wealth and knowledge are always in evidence, they can only be truly realised in countries or nations which are progressive. In the case of undeveloped or declining nations, these desires cannot overcome the general listlessness which prevails. The collective character lacks buoyancy, lively curiosity—energy and enterprise are absent. Therefore, while certain men may desire wealth, and others knowledge, they are, on the whole, unable to obtain freedom from the empire of routine. The general lethargic mind recoils with antipathy from novelty, whether it be in the form of industrial enterprise or intellectual innovation. Thus with nations, if the prevailing tendency is stagnation, then it is hardly possible for groups of individuals to escape the general trend. The tendencies of a nation are reflected in group units of that nation, and it is quite possible that among a progressive people, certain groups unsympathetic to the general advance may segregate. Such segregation is certainly shown in Germany, France and Great Britain.

Taking this group spirit as applicable to works, we find in some cases a predominant progressive spirit, and where this exists, there is no need to trouble as to the future of that particular establishment. There are other business concerns, however, in which the spirit is simply that of stagnation, and in which progressive effort merely results in stirring up the mud of the pools. When we meet men who proudly boast that their methods have never changed for thirty years, and who take pleasure in stating that what was good enough then is good enough now, we cannot help but be filled with sadness for the limited mental outlook of such individuals. That such pools of stagnation are to be found cannot be denied, and where found it is safe to state that neither the love of wealth, nor the love of knowledge, even though present in sufficient intensity as to result in a sacrifice of moral principle, will overcome the existing empire of old-established routine. The question may be asked: "What can one worker do if placed in circumstances in which every avenue is a retrograde one?" The answer is that he must do his duty according to his light, ever remembering that constant searching after truth will in time result in a clarification of the muddiest pool.

A note of warning is essential here, and this takes the form of stating that a real searcher after truth never despises the lessons of the past. In industry to-day, we build on foundations laid by our ancestors, and woe betide the man who, neglecting those foundations, attempts to build or create from his own puny knowledge. Many mistakes of the so-called modern spirit are to be traced to a feeling of self-sufficiency and casting adrift from all recognised bearings. Many of you have, no doubt, met individuals of this type, who, on the strength of a few months' experience in a technical school, know all that science has to offer and, as the result of a little ill-digested technical reading, become experts capable of explaining anything under the sun, bearing out the truth of the old saying that "A little knowledge is a dangerous thing." Avoid the individual whose knowledge is complete, and turn for information to the man who does not claim to know all.

The true modern spirit eagerly avails itself of all the help that can be gained from the records of the past. Building on past experience as a foundation it adds, slowly, brick by brick, of proved and tested

fact. Such a spirit recognises the limitations of existing knowledge and patiently tries to extend these limitations. It recognises that knowledge is never complete, and that each step gained emphasises the extent of the unknown. Gentlemen, it is our duty as leaders in one section of the industrial world to endeavour each in his own sphere and to the best of his ability to push back the barriers of the unknown. Let us remember that one solid fact gained is worth millions of dreamy conjectures, and that even if our progress apparently only consists in passing from one mistake to another, if the lessons of these mistakes are recognised and learnt, they will not have been without profit. The man who is genuinely in earnest learns more from his failures than his successes. The only disgrace connected with a mistake lies in non-recognition of the lesson it teaches.

This Association covers one of the least trodden fields of metallurgical activity, and while much has been written, very little actual work has been accomplished. As an Association of active workers, we expect every member to contribute his quota of solid work, and to give others the benefit of his observations when pioneering work has to be done. It is the duty of each member of this Association to apply himself to the development of foundry thought and real foundry progress. The days of the spectator have gone and, gentlemen, it rests with you to show that the "inside" man has more than a passing interest in the game. It is one that is worth playing, and further, is worth every possible endeavour, but it must be played squarely, with the sole object of promoting the advance of the art of founding metals which embraces metallurgical aspects in regard to brass, bronze, iron, steel and steel alloys, and includes great possibilities connected with moulding methods and materials. In another direction lie opportunities in the way of costing, estimating and management. The arts of management, accurate costing and intelligent selling, demand the application of much serious work, while the metallurgical possibilities of production and after-treatment are practically boundless.

Mr. H. Winterton (Birmingham) proposed a hearty vote of thanks to the Officers and Council for their work during the year. Many of them regretted the retirement of Mr. Kenyon from the Vice-Presidency. They had hoped very sincerely at some future time to have seen him occupying a still higher position. He could assure all the officers that the members regarded their work with the greatest confidence.

The vote was seconded by Mr. Mather (of Kent), and carried with acclamation.

The President's acknowledgment on behalf of his fellow officers concluded the formal business, and the meeting then proceeded to the reading of Papers.

Discussions on Papers.

Special Foundry Pig-Irons.

The first Paper read was by Mr. H. Pilkington, M.I.C.E., M.I.M.E. (Past President), on the subject of "Special Foundry Pig-irons."

Mr. F. J. Cook (Birmingham) said that the author had spoken of the erroneous idea existing as to low sulphur. Personally, he had been ridiculed many times for advocating sulphur for work to stand high temperatures and requiring good wearing qualities. He was sure that Mr. Pilkington was quite right in saying that a great many castings were condemned through sulphur, when sulphur had nothing to do with the defects. But it must be remembered that an iron containing high sulphur required to be melted and cast very hot. If that was done, he had no hesitation in saying that many of the troubles considered to arise through sulphur would very largely disappear. Sulphur defect was altogether counterbalanced by the good effects realised in the better physical properties of the metal. It was remarked that silicon introduced in the proportion of not over 1 per cent. was quite consistent with tensile strengths from 16 to 18 tons. That remark was quite within range, and if the silicon were not carried beyond 1.25 per cent. it would give good results and high strengths. One most important point not referred to related to carbon. He considered that the carbon content was the chief point in regard to the character of the iron, more particularly the total quantity present. The matter was either not referred to or sufficient weight was not given to it. His own contention was that the nearer they got to 3 per cent. in the total carbon the better would be the result, and it was no matter that they got their silicon, phosphorus and manganese in the right proportions, unless they also got the total carbon correct. With the silicon and the total carbon correct, say, not more than 3.25 per cent. total carbon, and not more than 1.25 per cent. of silicon, no bad effects would arise from the phosphorus, so long as it was kept within 1 per cent. If just below the 1 per cent., the benefit derived from fluidity and homogeneity would counterbalance any weakening effect due to the phosphorus in the metal. Mr. Pilkington had compared hot- and cold-blast irons, with the object of showing that the results of one were equal to the other. Unfortunately, he was unable to entirely agree with that statement. They might easily prove by chemical analysis that cold-blast iron and hot-blast iron were the same, but his own contention was that the physical properties of the two metals were very different. The question was a very debatable one, and his own opinion was that the carbon was more stable in cold-blast iron than in hot-blast. Probably they would remember the Paper which Mr. Hailstone, in conjunction with himself (Mr. Cook), gave at Birmingham, in which they showed that it was possible to have different irons of similar analyses and yet with physical properties entirely different. The condition of the carbon had a very considerable bearing on the difference between the two metals. He also quite agreed with Mr. Pilkington when he showed the absurdity of aiming at very low phosphorus iron by putting in hematite to bring it down. He quite agreed that hematite irons were not strong irons for foundry purposes.

Mr. J. Horne (Erith) said the Paper took him back to the time when he was directly connected with blast-furnace work. On many points Mr. Pilkington had made in his Paper as regards cold-blast and hot-blast, he did not think he could agree with him to any great extent, but with regard to the quality of cold-blast iron there was no doubt that that had deteriorated very considerably during the last few years. That, he was well aware, had been due to the fact that a good deal of the cold-blast iron formerly produced was not now being made. In the past it was produced from rich all-mine ore, but now they had manufacturers using lean all-mine, which to a great extent was now only worked in the old mining district, and probably Spanish ore. The ore now used was inferior to what they used to get. The result had been that the founder in buying what was nowadays called cold-blast iron did not get what he expected. During the last four years he had seen a considerable amount of melting done with what was called cold-blast iron. Mr. Pilkington did not agree with the founder who went in for mixtures in the cupola and re-melting that mixture for special work. During the last few years he (Mr. Horne) had seen a very considerable amount of work done in that direction. The results in

the castings had been everything they could wish for. They had not had any deleterious effects from occluded gases nor any great excess in wasters, so far as they could notice. In a foundry where there was a considerable amount of work done, and where they melted from 20 to 50 tons per day in the cupola, refining of iron in the cupola could be done with very great advantage. It did not necessitate the reducing of the cost in the foundry at the expense of quality of castings. By means of refining in the cupola they could utilise cheap hot-blast irons, which probably cost the foundryman anywhere from £1 to £4 less per ton, and to that extent the cost of special castings could be reduced, while tensile results would be quite satisfactory. If they could realise a tensile strength of 14 tons, that was quite good enough, considering the section that the designer always gave in cast-iron. They could cheapen considerably without reducing the strength of their results. With regard to the analysis of their refined iron, they had no difficulty whatever. It was possible to make up the mixture and run it down in the cupola and get the analysis just as they wanted it. But that meant that they must have a chemist in the foundry. Foundries as a rule did not buy 100 tons at a time of very special iron; probably the usual amount purchased was 5 or 10 tons, and they could not depend on the manufacturer giving them absolutely the same closeness of grain and the same analysis in every consignment, whereas, if they ran down their iron they would have iron of the same properties and of the same analysis every time. (Applause.)

Mr. E. Adamson (Sheffield) remarked that one of the first points touched upon was the question of refined iron. He believed that no one in the room had made so much refined iron as he (Mr. Adamson) had; therefore, he could speak with some certainty about refined iron, whether made in the Siemens furnace or by other means. The Siemens furnace, the air furnace, mixed the iron well, but as far as other means of making refined iron were concerned, he quite agreed that in refined irons there was not that homogeneity that the iron founders expected, more particularly if the foundry required a low silicon in iron in which, undoubtedly, steel was largely used. He did not approve of the use of steel in the iron foundry, simply from the point of view of want of homogeneity. Mr. Pilkington had hit the nail on the head when he spoke about carbon and its condition, and he was pleased also to find Mr. Cook expressing himself as he had on total carbon. He was quite at one with Mr. Pilkington on the question of tensile strength versus transverse strength. Mr. Pilkington had spoken also of low sulphur. One of the strongest irons that was ever made in the world was Finspong iron, which contained sulphur up to 0.14 and 0.15 per cent. It was possible to have 0.25 per cent. of sulphur and yet have a sound casting. He understood Mr. Pilkington to mean that a little phosphorus was helpful, and that a little manganese was helpful, but soundness in a casting was not primarily dependent upon either phosphorus or manganese. There was another remark to the effect that hard iron did not always give the highest tensile strength. He quite agreed with that. He had had test bars with over 3 per cent. of silicon giving 32 cwt. transverse strain and 0.8 deflection, with carbon at about 3 per cent. With regard to the proportion of phosphorus at 0.75 per cent, which had been referred to, according to a test published by himself, iron with phosphorus in the proportion of 1.2 persistently gave high results both in tensile and transverse tests. A proportion of 0.8 per cent. of phosphorus was not injurious to high tests, and they were safe if they did not get into the region of 1.5 of phosphorus.

Mr. P. Caddick said that with regard to the suggestion that they should do away with the transverse tests bars, he was rather surprised at that. They were all aware that there were a large number of foundries which had no call for the tensile test, because they required irons that had to stand high pressure. To his mind the transverse test was considerably better in that case, and he would be sorry to do away with the transverse test, although he would prefer the inch-square bar to the 2 in. by 1 in. bar. With regard to the question of sulphur, he thought the sulphur bogey was gradually dying away. His own view was that if they were invariably having trouble with sulphur, the cause was more likely to be in the coke than in the iron.

Mr. Pilkington, replying, said that Mr. Cook was quite right in alluding to the primary importance of the carbon content for such irons, as also was Mr. Adamson. It would be well known that in strong irons like those he had described the carbon never came up to anything like the percentage it did in soft irons. Therefore, naturally-made pig-irons contained more total carbon than any iron refined in any way whatever. Many of the remarks made by Mr. Mayer, Mr. Horne and others with regard to the practice of making the molten iron in cupolas and running it out into pigs for re-melting, related to practices with which he was familiar. Of course, re-melted iron must be more homogeneous than an iron melted from the first mixture; but he did not regard the cupola as anything of a mixer. Turning back to the real point of artificially-made pig-iron, it must be admitted that if in an air furnace or Siemens furnace the metal was really well melted and run properly it ought to be a proper mixture, but he had known a Siemens furnace where metal had not been properly melted and run down. In the Sheffield tool-steel trade they got a very high-class steel; they took their metal from one stock and one kind of iron; cemented it and melted it down as one iron, the reason being that there was no admixture in that metal. It was one thing melted down and used up again. He had at times seen many extreme analyses of pig-irons melted down in the cupola. He could not conceive how those who used them could expect them to mix. If they used hematite, they could not get the requisite metalloids or the manganese of the metals to the point at which they should be used, and he believed Mr. Cook agreed with that. He agreed with the remarks by Mr. Cook about phosphorus, though they were not universally believed in. With regard to some remarks made by Mr. Horne, there was a good deal of confusion existing; necessarily, the oxygen got into the re-melt because of the nature of the scrap used. That was one of the most important things in connection with the purchase of re-melted iron which users should be warned against. Mr. Horne had made a remark that they could not buy cold-blast iron as it was once bought, and he believed that they never would again. Partly, that accounted for the Paper that he had given, and for the demand which he felt certain existed on all hands. They had not the same ores, and they had not also the same practice that they used to have. He believed all the old managers who once made cold-blast iron were now dead, and he regarded himself as only a kind of coupling link between the old and the modern generation. He had laid some stress on the superiority of the tensile over the transverse test bars. But he was quite aware that the transverse test bar was a great friend of the ironfounder, and as long as the experts of Great George Street were fond of it, other people would also be fond of it; but they must not forget that it would let them down. The transverse test bar was not reliable, but

the tensile test bar would never let them down if it was honestly used.

The CHAIRMAN remarked that they all desired to tender to Mr. Pilkington their heartiest thanks for his very able Paper.

Carbon Control in Cast Iron.

The next Paper on the programme was the one by Professor Campion on "Steel Castings," but as he was unable to attend until the following day, it was decided to take the Paper by Mr. R. Buchanan, F.R.S.A., on "Carbon Control in Cast Iron." This Paper was accordingly read.

MR. BUCHANAN remarked that he had suggested the preparation of a glossary of technical terms as a valuable means of reference to practical men who had not had a course of technical training.

MR. J. HORNE (Erith), opening the discussion, said that on page 4 Mr. Buchanan had brought out an idea with regard to the saturation point of carbon. Mr. Buchanan said: "Either the iron becomes saturated at 4.3 per cent. carbon, or too much silicon has been reduced by the excessive temperature, with the result that the silicon, if present to the amount of 4 per cent. to 5 per cent., lowers the power of the iron to absorb carbon even at these high temperatures." On that he would remark that he did not think it was at all a decided point up to the present as to what really was the saturation point of iron for carbon, and they might hear something further on that subject. It was possible that iron might contain carbon to a much greater extent. On page 5 there was a remark as to the taking up of the carbon. Mr. Buchanan said: "If the melted and melting iron is in contact with excessive free carbon it is only to be expected that it will take up more carbon seeing it has a capacity for more, being not yet fully saturated." With regard to that, the question arose in his mind as to whether the iron took up carbon from simple contact with the carbon in the coke. His own idea had always been that the carbon was taken up by the iron from a certain gaseous condition, probably from carbon in the form of carbon-monoxide, and he did not think it right to say that iron took up carbon from contact with the carbon of the coke. Further, it did not follow necessarily that if they had more coke than the cupola could burn, that the excess carbon would be dissolved by the iron. Another question related to the appearance of kish in castings. In all his experience, extending over sixteen years, he had never yet seen kish on a foundry casting. He had seen kish many a time on the surface of a direct casting from the blast furnace, but never from the cupola, and he did not suppose that the foundries he had been in were more scientific or more perfect as regards cupola practice than in those cases where the kish had been so visible. Personally, he could not see how iron melted in a cold-blast cupola could have carbon present in such a condition that they would have it separating out as kish on the exterior of the casting. Regarding the use of steel, Mr. Buchanan had stated that there was a great future for the use of steel in the foundry. That appeared to suggest that founders had probably got to the point Mr. Pilkington mentioned of the cheapening of mixtures to produce cheaper iron. In his own case he had had experience in the use of steel for some years, with very satisfactory and very accurate results. It had cheapened the mixture of the foundry. They had had no trouble from the point of view of the non-melting of steel, and no trouble from spots in the castings. They had produced castings which were not hard, and which were easier to machine than when they were working with close-grained iron, and in that way they had been able to cheapen the product very considerably. He did not know that his scientific theory was correct, but what he thought took place in the cupola was that the steel absorbed carbon at or near the melting zone, thus lowering the melting temperature of the steel. He could give some experiences on that. The steel on many occasions had been melted and appeared at the tapping hole before the pig-iron was melted so that probably his theory was correct. The question arose, how did unmelted steel get into the iron, and how did the steel spots occur in the castings? There was one reason which had been suggested. The melters in dealing with the cupola were in the habit of putting a bed of coke in first and having the steel scrap on the top of the bed of coke and the pig-iron on the top of that. In his view that was the main reason for unmelted steel and steel spots in the castings. The better practice was to have the pig-iron on a bed of coke, and on the top of that to put in the scrap, finishing up with the steel in the form of scrap plate and punchings. They used a little more coke, but not much. He would not recommend any foundryman to work with steel who did not know the composition of his pig-iron, for without that knowledge steel would always give trouble. If they knew the composition of the pig-iron from day to day they could make use of steel to much greater advantage. The iron produced for foundry purposes from pig-iron and scrap had stood a strain of 12 tons in the tensile tests, and by using 10 per cent. of steel they could bring up that tensile strain to 14, 15, or 16 tons. A further point he would like to mention related to the carbon content. He did not think that the carbon content was altered by the addition of steel, and he certainly did not think that they reduced the percentage of carbon in the mixture. In dealing with the effect which the steel had on the mixture, there again he was unable to give facts; but, taking the result of examination of microscopic sections, he thought the effect was to raise the temperature of the freezing point. The iron would freeze more quickly, and the graphite flakes would consequently be much smaller and the strength increased considerably.

MR. F. J. COOK (Birmingham) said it seemed that Mr. Buchanan was rather against the application of the cupola for refining, and he had also said that a very great effect took place, but he had only dealt with one effect, and that was its bad effect. But there was very much to be said for the other side. They could get a good effect if they knew what they were doing. One of the things which struck him most with regard to foundry work was the lack of intelligence in respect to blast pressure in cupola working, and it was quite an exception to find a man in the foundry who knew what he was doing in his cupola. In particular, he did not know whether he was softening or hardening his iron. All he knew was that he sometimes got a bad result, and did not know why. On this it was for each one to practice, and follow up his experiments by careful testing; then they would know how the cupola was working. He had a Bristol recorder connected with every cupola, recording the blast utilised throughout the full extent of the blow, which he examined at 9 o'clock every morning, and he found that very valuable in making cylinder iron and similar material, so that he could rely upon his results with regard to hardness and tensile strength, but such reliance could only be obtained by years of practice.

Mr. W. H. Sherburn (Warrington) asked Mr. Buchanan whether he considered his was an exactly true analogy of what took place with regard to carbon in iron, and if so, whether, when carbon came in contact with iron it would dissolve as much as possible and keep it in perfect solution, because that would be the effect of tea upon sugar. Mr. Horne said he was not quite sure himself how carbon was taken into the iron, whether as solid carbon, or whether it was taken in the gaseous state from the coke.

Mr. Buchanan, replying to the discussion, said that while he appreciated Mr. Horne's criticism he would like also to express his sense of the very valuable character of his remarks on the mixture of steel with iron. With regard to Mr. Sherburn's point as regards the saturation of iron by carbon, he believed that 4.3 per cent. was about the saturation point in normally grey iron. Of course, with ferro-manganese of 80 per cent. manganese you could have 6 per cent. of total carbon and perhaps over that, but the 4.3 per cent. was a normal grey iron produced under normal furnace conditions. Mr. Horne had said that he had never seen kish in a foundry casting. That was one of his (Mr. Buchanan's) earliest recollections in his apprenticeship. He saw kish in a casting, and when the machinist went to drill it, while the casting was brilliant with bright specks, he could not get the drill in it. He had seen kish on several occasions, and sometimes he saw carbon flying off while the man was carrying the metal through the foundry. That meant that it had taken up so much carbon in the cupola, while being melted, that as soon as it dropped a little in temperature the mechanical motion of the ladle assisted the carbon to come out in the form of kish. When iron dropped down to about a thousand degrees of temperature in the mould it could not carry the high amount of carbon any longer, and it came out as graphite. He had already replied partly to Mr. Sherburn as regards the saturation of carbon in the iron. With regard to the analogy of sugar, he was not at all surprised that Mr. Sherburn should call it in question. Personally, he did not know sufficient of the subject to maintain the illustration through thick and thin, but so far as he used it he considered the analogy correct. They would melt more sugar in hot tea than in cold, and they would dissolve, or melt, more carbon in hot iron than in cold, and so far the analogy was true, but it was simply used as an illustration.

In conclusion, the Chairman expressed the thanks of the meeting to Mr. Buchanan for his excellent Paper.

Warping in Castings.

Mr. R. R. McGowan (Glasgow) read a Paper on "Warping in Castings."

Mr. C. Heggie (Birmingham) said they all agreed that the reason camber was needed was due to the metal cooling more quickly on the edges. He did not agree that there was a different action between the two bars exhibited. The action that took place was through the cooling from the outside. It was only a matter of the time taken in cooling down, and that caused a difference in contraction. The difference was not caused by the holding of the liquid metal. That more open section was due to the more liquid carbon that had separated out. Professor Turner had made some experiments with a half-inch section bar, and Mr. Keep, of America, with an inch bar; and they found not only contraction, but also expansion. There were three different arrestments which took place with the inch bar, and while the inch bar took 11 minutes to cool down to a certain temperature, Professor Turner found that his bar took only 4½ minutes. There were the same arrestments, and they could imagine the warping that would go on when they got a variation in the rate of cooling as between half an inch and an inch or larger thickness. If the pattern-maker would give them more regular patterns, the foundrymen would do better.

Mr. W. H. Sherburn (Warrington) said that no doubt if the three-inch bar had been chilled at the same rate as the one-inch bar, the contraction, as Mr. Heggie suggested, would have been the same. He totally disagreed with the use now made of the two words "shrinkage" and "contraction," as if they meant different things, and it was about time that they defined their terms somewhat better. When he turned to the dictionary and read the meaning of contraction he was told it meant shrinkage, and if he turned up the word "shrinkage," he found it meant contraction. (Laughter.) He noticed that the reader of the Paper said that the shrinkage took place while the metal was liquid and contraction while it was solid. But his contention was that the same action took place in both cases. No doubt both designer and pattern-maker could do much to overcome warping and strain, but they had constructional and commercial considerations to deal with, which prevented the adjustment of thickness, which would prevent warping. Some sections—especially channels—must be as light as possible, therefore camber—an annoying makeshift—must necessarily be resorted to.

Mr. R. Buchanan (Birmingham) said that he thought that warping was largely a matter of expansion and not contraction. If they took the two edges of that channel they were cooling first, and Professor Turner had shown that the casting at a given point in its cooling was actually longer than the pattern. If those two edges were cooling at that point, the cooling down would result in the making of a curved form, and that expansion of the edges would cause compression of the still plastic flat part. It was the expansion of those two edges which caused the trouble, and owing to the plasticity of the iron, the curves took place, and the flat part as it cooled down was unable to compress the rounded portion back again. When they had got the "H" section, they had got both rapidly-cooling edges acting in the same direction on the opposite sides, and that caused the trouble to be avoided, with the result that the casting was straight.

Mr. McGowan, replying to the discussion, said he agreed with Mr. Heggie with regard to the light and heavy bar referred to in the paper, that the heavy bar, if cooled more quickly than the light bar, could be made to contract to the same amount. It was possible with some castings to balance the rate of cooling by chilling some parts and thinning other parts, but this was not so with certain castings such as those of a channel section. In some cases these castings were less than one-eighth inch in thickness, and could neither be chilled nor thinned, as they were as thin as it was possible to cast them. Therefore they must meet the conditions as they found them and camber their patterns. He thanked Mr. Buchanan for his opinion regarding the cause of warping, although he was not inclined to say whether he was right or wrong. The theory put forward was that which had occurred to him, and he would leave the decision to the opinion of the members.

Wednesday's Proceedings.

On resuming their proceedings on Wednesday, the Convention considered first the Paper read by Cecil H. Desch, D.Sc., Ph.D., on "The Crystallisation of Cast Metals."

The CHAIRMAN said that Dr. Desch had given them an excellent introduction to general metallography, and the next Paper, by Mr. J. S. G. Primrose, A.G.T.C., A.I.M.M., (Metallurgical Department Glasgow Technical College), on the subject of "Metallography as an Aid to the Ironfounder," might very properly be taken at the same time, and discussed conjointly with Dr. Desch's Paper.

Crystallisation of Metals and Metallography as an Aid to the Ironfounder.

PROFESSOR CAMPION (Glasgow) said that both Papers were very admirable, and one had a bearing on the other to a considerable extent. Dr. Desch had dealt in an excellent manner with some fundamental principles, but at the end of his Paper he appeared to be somewhat too modest, when he said that he did not hope that those remarks would be of much use for foundry trades. That was a sentence which he was disposed to criticise most severely, because he thought that it did apply to a very large extent indeed. In fact, the whole strength and reliability of castings depended upon their having a suitable form of crystallisation, and if they were not in that proper form, they must try to get a rearrangement of the crystallisation so as to give a reliable metal, and that required to be done with heat treatment in the case of iron and steel alloys. As regards microscopic examination, he would like to emphasise very much what a large amount of useful work could be done with very simple apparatus. With a hand lens, a few simple pieces of paper, and a microscope of moderate price, very good work could be done, and research work carried out which might be much more useful in a commercial sense than work carried out in a laboratory. A few fundamental principles needed to be mastered, and in the case of some workmen, possibly these were beyond their reach through want of training or apparatus. But when points were once determined they could be put in such a simple way, that the worker could apply them, and find them of very great use in everyday work.

MR. R. BUCHANAN (Birmingham) said he would like to ask Dr. Desch whether he could throw any light on a question of crystallisation. They sometimes noticed in a chilled roll and similar castings a clear line of demarcation between the white portion of the roll and the grey centre, and similar rolls cast from other irons would show an interlocking of the white crystals with those of the mottled or grey crystals, and that gave them a very distinctive appearance. Practical people who used rolls preferred those in which the white crystals were interlocked with the grey, because there was less liability of portions of the metal coming off. Was it possible to throw any light on the conditions which produced those various appearances? In Mr. Primrose's Paper it had been shown that a marked change took place in the appearance of the iron from the addition of a small percentage of aluminium. He was not at all clear as to the particular function which aluminium played in cast iron unless in one direction. He knew that when it was added to the extent of 2 per cent. into grid castings intended for electrical resistance, that resistance was distinctly increased, but in regard to the effect of aluminium generally, that subject did not appear to have been very thoroughly thrashed out. His impression was that the original investigations showed that the effect was somewhat in the same direction as silicon. He had not been following that question very closely and he would like to have some information on that point. Another question referred to was the blow-hole question, and the bearing upon them of the globules of phosphide. It would be within the recollection of many of the members that Mr. Munnock had dealt with that question, and had proved pretty conclusively that it was phosphides which filled in some of those blowholes. On a recent occasion he had an opportunity of examining one of those globules in which one could trace where the turning-tool had passed over this surface, shewing that the globule was not excessively hard. When the globule was analysed the sulphur was really lower in that part than in the general body of the casting where the grey metal was. Personally, he was pretty certain that the blow-hole and the globule were the result of two quite different things. The blow-hole was formed and the globule was extruded into the cavity.

MR. W. MAYER (Dumbarton) said Dr. Desch had alluded to steel ingots in his references to crystallization, and he would like to have an explanation of what would be the result, supposing that an ingot of steel could be prevented from expanding in the way it did just before the final settling stage—if the ingot mould could be held on tight instead of expanding as in the common practice. The mould expanded and the ingot contracted, and so there was a clear space between the shell of the ingot and the ingot mould. It was still quite fluid inside, and as time passed, and it got more into the settling stage, then there was an expansion collapse. That development was seen to a greater extent in the steel ingot than in any ordinary iron casting. There were thin feather marks and tiny fractures to be seen if examined with a highly magnifying glass. Sometimes they could find that the steel had oozed out and gone into thin flakes, in the space between the ingot mould and ingot. He was disposed to differ from Mr. Buchanan in regard to the general question of blow-holes. He thought the fault was not so much in the metal but very largely owing to the shot corns in the moulding sands rather than to the metal. There was a great deal in the way moulds were cast, and sometimes there was all the difference between laying the metal on when casting a mould to throwing it on. If they threw it on they would make shot corns and splashes. Personally he had made the runners go into the mould and splash, with the result that they produced shot corns. In making moulds, he believed that the sand was not always properly prepared, and sometimes nuts or small bits of sand like shot were distributed through the bulk of the ordinary fine sand surrounding it. That sand might possibly be slightly damper than the other, and having more dampness or moisture the sand lying close to the bottom of the mould caused rarifaction of the air and moisture in it, and made the steam issue on the bottom side. That, he thought, accounted for a good number of the blow-holes. Porous sands down near the bottom of the casting were very apt to be moister than the sand elsewhere.

MR. J. HORNE (Erith) said he had listened with extreme interest to the last speaker, and leaving science and metallography out of the question, he thought he had hit the nail on the head. That question of shot in the castings was due entirely to the condition of the mould and to the temperature of the metal in its relation to the mould in which the casting was poured. Mr. Primrose, in his Paper, talking about shot, had considered the question of phosphide eutectic. It was a well-known scientific fact that the phosphide in the cast-iron was the last to solidify, and he thought the President would back him up in that. In fact, in his book, he had given them information that he had on occasions found phosphorus up to something like 10 per cent. in castings where

shrinkage had taken place. Mr. Primrose, in his Paper, appeared to have come to the conclusion that the shot was entirely due to phosphide of iron, but the shot existed in the ladle, and the question arose as to how it was formed there. Did it come down from the cupola? Personally, he did not think so. If it was in the ladle, the only way it could come there was in the running from the cupola into the bottom of the ladle and forming shot by splashing—a case of chilling. But how did the phosphide come into the skin of that shot? It was shown in the photomicrograph that while the centre of the shot was good iron, the outside of it showed phosphide eutectic. The question was still unanswered as to its origin. If it was in the ladle as shot, then it was poured into the casting, and in the skin of the cavity there was again said to be the phosphide eutectic. It was said that the cause was a chilling action, but personally he did not think that that was the true explanation. From the practical side it was clear that the pouring of iron at too low a temperature into the mould formed shot by splashing on the bottom; this got into the iron and chilled it at that point. He quite agreed with all the speakers with regard to sulphur, but he did not think that where they wanted a special iron for cylinder work or any special hydraulic work one need worry about sulphur up to quite 0.15 per cent. His experience was that he had had up to 0.14 or 0.15 very frequently. It did not harden the metal, and up to that extent there was no trouble with blow-holes in the casting.

Mr. H. Jewson (Dereham) said that he had been exceedingly interested in the last two Papers, and particularly in the remarks of the last two speakers. The question of hard shot in the castings was, of course, of very great interest to foundrymen. But it seemed to him that the two last speakers had dealt with different classes of shot. Possibly Mr. Buchanan might be right so far as phosphide shot was concerned, but the shot that caused the most trouble was the hard shot found in the heart of the casting. When the casting got into the machine they found a hard spot deep down in the casting, which destroyed all the drills, and that was quite distinct from the shot found on the surface, which might very well be caused by splashes. The difficulty he had experienced arose when he was using almost a pure No. 1 Scotch iron, but when he materially increased his proportion of scrap the trouble with the hard spots in the centre of the casting disappeared, and he had not had any trouble with that for years.

Dr. Desch, replying to the discussion, said there were only two or three points to which he wished to refer. Mr. Buchanan had asked a question as to the boundary between the grey and white iron in chilled rolls. He himself had noticed that very remarkable sharpness occasionally observed at the boundary. The transformation of white into grey iron took place in just the same way as the process of crystallisation from a liquid. The separation of graphite began at a number of nuclei in the white iron, causing its conversion into grey iron, that is, from a less stable into a more stable condition. Just as crystals grew outwards from a centre, so the transformation of grey into white iron proceeded outwards. The principles governing the appearance and distribution of the nuclei were very obscure. Occasionally the nuclei had a habit of appearing symmetrically, giving a regular boundary, but as to what determined such an arrangement he was afraid he was not in a position to say. As regarded Mr. Buchanan's other remarks, he was very glad to hear his explanation of the formation of those shots which appeared in blow-holes. He thought his explanation of the eutectic being squeezed out as from a sponge fully met the case. But whether that explained the formation of shots in all cases was quite another question. It was possible that many of the hard shots directly embedded in the metal might have a different origin. At all events, that explanation applied to those which appeared in blow-holes. As regarded the piping in ingots, the formation of the pipes was due to purely mechanical causes. They were due to contraction and their cure would seem to be a mechanical matter. There were chemical methods of diminishing piping which were more or less successful, but it seemed to him that whilst the addition of certain materials was useful the only real cure for piping in steel ingots was a method of fluid compression and no other methods would get over it completely.

Mr. J. S. G. Primrose, also replying, said that the questions put by Mr. Buchanan related first of all to the use of aluminium. The employment of that metal had been very fully investigated in regard to steel, and Mr. Talbot had advocated it as a prevention of the piping in ingots, for which it had been found successful. Its effect on cast-iron was similar to that of silicon, but it was not fully known what effect traces of aluminium had. It seemed, however, in small quantities to hasten the rate of cooling and cause the formation of smaller aggregates of the crystals. When they had as much as 2 per cent. added, some of the aluminium would remain as an alloy, but when used in such a small quantity as that mentioned in the Paper, none of it remained, and therefore its only effect was the physical one of diminishing the size of the graphite flakes and strengthening the metal. Mr. Mayer had pointed out the effect of inequalities in the moulding-sand forming blow-holes, but this was only the case when drying was not complete. In Mr. Munnoch's Paper the question of blow-holes was fully dealt with, and his (Mr. Primrose's) reason for taking up the question was to combat the view put forward by Mr. West at the recent American Foundrymen's Convention. Mr. West seemed to hold an opposite opinion to that of Mr. Munnoch, and he (Mr. Primrose) wanted to show, from the metallographic standpoint, that phosphide was chiefly the cause. With regard to Mr. Horne's remarks, he had to admit that what he advanced with regard to the formation of "shot corns" was purely a theory. As to where the phosphide came from, the phosphorus was in the iron, not as phosphorus, but as phosphide, so that each part of phosphorus represented 6.42 parts of phosphide. It was in the metal to start with, and as its melting-point was lower than that of the cast-iron, it would naturally melt first and come down very much more rapidly than the iron; and being different in density from the iron, it would tend to remain separate, however vigorous the stirring which the iron received, and as it was not usual to give such stirring, it was likely to remain separate. They might take the analogy of the soap bubble. They knew how very thin was the film of soap and water, and yet that was able to keep apart from contact with the outer air the air enclosed in the bubble, and so it remained for a considerable time until the bubble burst. Something similar seemed to hold in regard to the iron phosphide. When it was not present in sufficient quantity to form a globule, yet in the liquid state it could enclose a portion of the metal as a bubble, and so retain it until the phosphide film or the actual surface was broken. That was purely a theory, which he was unable to substantiate, unless by one or two instances of globules which did not show the phosphide eutectic in excess in the globule, yet were very well marked at the edges both of the globules themselves and of the cavities in which they occurred.

Presentation to Mr. F. J. Cook.

The PRESIDENT said that on the previous day an interesting little function was omitted, owing to the pressure of other business. One of the chief advantages of the Association, and one which he himself highly appreciated, was the fact that it was bringing together a set of men who were becoming leaders of British foundry thought. If for no other reason, the existence of that Association had been justified by the bringing before the foundries of the country men like Messrs. Buchanan and Cook. His own personal feeling had been that the greatest advantage of all had been the meeting together and mingling for social and intellectual as well as for purely technical purposes. (Hear, hear). Mr. Cook, during his term of office as President of the Association, gave himself heart and soul to the work. The President continued, addressing Mr. Cook: "The members of the Association, Mr. Cook, have decided to make some small recognition of your work, your very valuable work, for this Association, and they trust that in accepting this framed statement of our appreciation you will ever remember that through the joys of your office you to some extent forgot the arduousness of the work involved. It has been a custom to present Presidents with a record of this kind, but in this case it is especially pleasant to me to make the presentation." The address reads as follows:—

"To Mr. Frederick J. Cook.

"We, the members of the British Foundrymen's Association, desire to place upon record your distinguished and valuable services as President during the years 1908-9 and 1909-10. During your Presidency the Association grew greatly in numbers and influence, largely through your initiative and example, and to mark our appreciation of your eminent services, and our high regard and esteem, we have much pleasure in asking your acceptance of this address.

Signed on behalf of the members of the Association,

PERCY LONGMUIR, B.Met., President.
C. JONES, Senior Vice-President.
SIDNEY M. GIMSON, Junior Vice-President,
J. E. H. ALLBUTT, Honorary Secretary."

August, 1911.

MR. F. J. COOK acknowledged in very appreciative terms the presentation from the members.

Notes on the Treatment of Steel Castings.

PROFESSOR A. CAMPION, F.I.C. (of the Glasgow and West of Scotland Technical College) read his Paper on "Notes on the Treatment of Steel Castings," which, however, did not elicit discussion of any great importance.

PROFESSOR CAMPION, replying, said he believed the only point was one raised by Mr. Cook in regard to the difference between Continental and British castings. It was possible that some of that difference might be due to the method of annealing, and some of it to the method of manufacture. He would not like to say which. According to his experience, he should say that the difference might be about equally attributed to each of the two causes. In the Continental houses they paid more attention to those points than in this country. Instead of leaving heating to the labourer, they generally had someone who watched him and systematised his method of working, and possibly that explained the good quality of steel produced in Continental practice. In Krupp's great works they made large castings by the crucible process, much larger than in this country, and to that practice might be due the excellent quality of the castings to a considerable extent. He was very glad to hear their recognition of some points that had been raised, and he hoped that would set some people thinking, and so bear fruit later on. The larger organisations were in the habit of controlling their works to a large extent. With regard to the absence of discussion, he was afraid it was quite true in other places besides Sheffield, there was a great disinclination to discuss questions of steel.

Art as Expressed in Castings.

The last Paper on the list was on the subject of "Art Expressed in Castings," by MR. W. F. BAGNALL (Sheffield). An excellent series of slides was exhibited, which were explained at some length by Mr. Bagnall.

An interesting discussion of a non-technical nature followed.

The Lord Provost's Reception.

On Wednesday evening the Lord Provost and magistrates of Glasgow entertained the members of the Convention and a large number of the local foundrymen, with their lady friends, in the City Chambers of the Council buildings, where a number of prominent local gentlemen and ladies were also invited to meet them.

Visits to Works.

G. & J. Weir, Limited.

The visit paid on the Tuesday afternoon to the works of Messrs. G. & J. Weir, Limited, Holin Foundry, Cathcart, was one of exceeding interest. The works are devoted chiefly to the manufacture of the firm's specialities in marine auxiliary machinery. "Weir's auxiliaries," which appear in specifications for marine steam power in every part of the world, comprise direct-acting feed pumps, service pumps, independent air pumps, marine evaporating and distilling plants, feed-water heaters, etc. The firm are contractors to 22 Governments and to the leading mail and passenger steamship lines throughout the world. The visitors, therefore, had an exceptional opportunity of witnessing arrangements for the production of work of the highest grade. The works cover 13 acres, and are laid out on the most modern lines, comprising pattern shops, iron foundry, brass foundry, smithy, copper shop, machine and erecting shops complete.

The iron foundry is a steel structure 270 feet long by 210 feet broad, and has three Thwaites' cupolas with blast furnished by Root's blowers. The three main bays are served by five electric cranes, while the central floor is served by six hydraulic cranes for closing boxes, etc. The brass foundry has 17 crucible furnaces and two reverberatory furnaces, and a large sand-blast plant for cleaning castings. Both foundries have extensive stove accommodation for drying complete moulds. These stoves are provided with large carriages. Moulding machines of both English and American make are used on the small duplicate work. Most of these machines are of the stripping-plate variety.

The brass foundry is particularly interesting. The pump cylinders, air pump chambers, and other gun-metal parts of Weir pumps are cast here. As a great part of the work has to meet the requirements of British or foreign Admiralties, the castings are subjected to very severe tests before acceptance. Some of the air-pump parts are very intricate in character, and the excellent character of the work turned out reflects great credit on the employees. A striking feature of the foundries is their high roofs, affording excellent ventilation and an abundance of light. The general roominess of the bays and the wide gangways also attract attention. The two foundries give employment to some 425 men. A laboratory and a testing department attached to the foundries check and

FIG. 1.—BRASS FOUNDRY: WORKS OF MESSRS. G. & J. WEIR, LIMITED, CATHCART, GLASGOW.

FIG. 2.—SMALL OVEN AND CORE SHOP: IRON FOUNDRY OF MESSRS. G. & J. WEIR, LIMITED, CATHCART, GLASGOW.

supervise their products. The metallurgical laboratory, which is under the direction of Mr. H. S. Primrose, is one of the finest in the kingdom.

The main machine shop consists of ten bays 330 feet long, and is equipped with plant of the very latest design by British, American and Continental manufacturers. The power is furnished partly by gas engines working on suction gas and partly by electric current supplied by the Clyde Valley Electric Power Company. The departmental sections include stores, tool room, gauge department, etc. The erecting, water testing and steam testing shop consists of four bays 375 feet long, equipped with electric travelling cranes, and at the steam-testing platform with hydraulic jib cranes. The small pump department is a reproduction in little of the large shops, and has a special automatic department for the production of duplicate parts in quantity.

Commercial and drawing offices complete the establishment, which is in point of equipment, system and organisation one of the most advanced and interesting in the country. One of the great features of the establishment is the extent to which standardisation is carried and interchangeability secured by a system of regular inspection.

The North British Locomotive Works.

On the Wednesday afternoon, the members of the Convention journeyed to Springburn, where a visit was paid to the Hyde Park Works of the North British Locomotive Company, Limited. The Company works consist of three fully-equipped and independent units, namely, the Hyde Park Works, formerly Neilson, Reid & Company, the Atlas Works, formerly Sharp, Stewart & Company, and the Queen's Park Works, formerly Dubbs & Company. The last-named is situated in Polmadie, and the other two in Springburn. The administration buildings are in Flemington Street, Springburn, and comprise, in addition to the usual accommodation for the Directors, offices for the entire commercial staff and for the technical and drawing departments. The combined output of the three works now exceeds 20,000 engines, and the capacity per annum is about 700 main-line engines of the highest grade of material and workmanship, in addition to a number of smaller engines. The whole establishment, resulting from an amalgamation of a number of the largest works in North Britain, forms a combination believed to be the largest of its kind. All the buildings and machinery are well-designed, and embody the latest ideas in regard to plant. The shops are exceptionally large and well-lighted.

The time available was sufficient for a rapid inspection of the Hyde Park Works only, the manager of which is Mr. Hugh Reid, and the works manager Mr. McGregor. On the north side are the joinery and pattern-making shops, pattern stores, and the brass and iron foundries, with cupolas, core-drying stoves, etc. These shops are detached from the main group, but conveniently situated with regard to it. Along the centre of the works, from north to south, are ranged the template shop, cab shop, boiler-mounting shop, boiler shop, and the smithy and forge in one general group. The western side is occupied by the wheel and fitting shops, machine shop (recently reconstructed), finishing shop, and light turning and tool grinding shop. Between these two main groups are the power stations, including boiler house, electric power house and pneumatic power house. At the east end are the heavy tool shop, paint shop, and material store. Near these are the tender and tank shops and the cylinder departments. Although these are situated at some distance from the engine-erecting shops, they are in direct communication with them by rail and overhead cranes.

The crane equipment of the works is complete and efficient. All the shops are well provided with overhead travelling or walking jib cranes, varying from 90 tons to five tons, and all electrically driven. The steam pressure throughout is 200 lbs. per square inch, except in the forge, where it is reduced to 65 lbs. The electric current is continuous at 250 volts. Hydraulic pressure is also largely requisitioned, principally for the great amount of press work required in connection with the framing of the engines, and the hydraulic pressure available is 1,500 lbs. to the square inch.

Engines are turned out at these and the allied works practically for all the railways of the world. Among the railways for which a large amount of work is being done at present are the Indian State Railways, the Australian Railways, the Egyptian Railways, and a number of American lines, as well as some of the new lines constructed, or in course of construction in the more recently-opened parts of Africa. Not only are all the shops spacious, but provision in most cases has been made for extensions. The various arrangements in the way of dining-rooms, recreation-rooms, etc., attest the consideration of the Company for the comfort and social well-being of the workpeople, and the works, as far as a brief inspection enabled one to judge, are a model of constructive and administrative convenience and efficiency.

Boat Excursion on the Clyde.

Thursday was devoted entirely to a sail on the Firth of Clyde, through the Kyles of Bute and round the Isle of Arran. The steamer "The Duchess of Argyll," which is one of the most modern and comfortable boats plying on the river, was placed at the disposal of the party. A large number took advantage of this opportunity of seeing some of the most beautiful of Scotch scenery, and the city of Glasgow was reached by special train shortly before seven o'clock.

The Glasgow and West of Scotland Technical College.

Considerable interest was taken by the visitors in the Glasgow and West of Scotland Technical College, generally recognised as the most suitable meeting-place for the Convention. This is one of the finest institutions of the kind in the kingdom. It has the distinction of being the first college of the kind established, being founded as far back as the year 1796. The first section of the present building was opened in 1905, the same year in which the Foundrymen held their first Glasgow Convention. The last section was completed only last year. The entire institution cost over £400,000, and occupies the largest building in the kingdom devoted to technical education. The equipment of the engineering laboratories includes a horizontal testing machine of 100 tons capacity, taking specimens up to 12 feet long in tension and beams 15 feet long. A vertical testing machine of 12,000 lbs. capacity and many special forms of testing machines. In the metallurgical department, situated on the third floor, there is a furnace room and general laboratory for analytical work, a room for pyrometry and metallography, and among the most recent extensions are apparatus for melting, casting and treating metals and alloys, as well as for the testing of ores. The laboratories are very well equipped with apparatus for metallurgical analysis and experiments. There are gas and coke muffle furnaces, a Whiting cupola, capable of melting a ton per hour, a tilting crucible melting furnace of the M.R.V. type, moulding boxes, tools, ladles and the usual foundry accessories. Many members of the Conference took the opportunity of inspecting the technical department.

FIG. 3.—GENERAL VIEW; FOUNDRY OF MESSRS. G. & J. WEIR, LIMITED, CATHCART, GLASGOW.

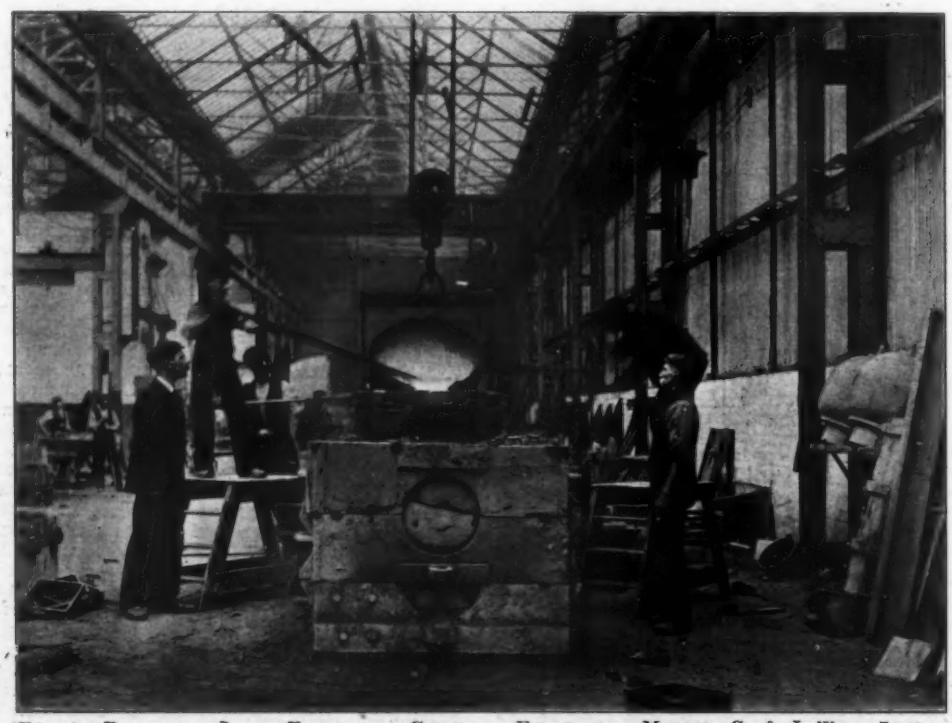


FIG. 4.—POURING A LARGE EVAPORATOR CASTING: FOUNDRY OF MESSRS. G. & J. WEIR, LIMITED, CATHCART, GLASGOW.

Carbon Control in Cast Iron.

By Robert Buchanan, F.R.S.A. (Birmingham).

Carbon will dissolve in grey iron in all proportions up to fully 4 per cent. carbon, and is then said to be "saturated," that is, this iron will not dissolve any more carbon. This will remain dissolved if the iron be cooled quickly. With the large percentages of carbon, some of it will re-appear as graphite if the cooling be prolonged. That is, it comes out of the dissolved, or invisible form, and becomes visible as graphite. If this iron be kept at a temperature of about 1000 degrees Centigrade (1.832 degrees F.) for a period of several hours, the amount of graphite extruded will be greater than if the iron were kept at the same temperature during a less period of time. This illustrates the importance of the "time element." The time element is important when considered in relation to light and heavy castings, and it is not less important as related to test bars.

In the molten iron the carbon is wholly dissolved, or, as it is termed, the carbon is in "solution." There need be no more difficulty in understanding the dissolving of carbon in molten iron than there is a difficulty about understanding the dissolving of sugar in a cup of hot tea. Hot tea will dissolve more sugar than cold tea will. Hot iron will dissolve more carbon than dull iron will. Whether you have dissolved sugar in tea, or carbon in iron, if each is allowed to cool, the tea will drop some of the sugar out of solution, and you will find it at the bottom of the cup; and the iron in cooling will allow some of the carbon to come out of solution and re-appear as graphite. All the sugar will not be deposited at the bottom of the cup; some will still remain dissolved in the tea. So with the iron (unless special means are employed), on cooling down some of the carbon will be deposited as graphite, and some of the carbon will still remain dissolved in the iron. This carbon remains dissolved in the iron until, and after, the iron is solid. This carbon is then said to be in "solid solution"; that is, some of the carbon is still in a dissolved condition although the iron is solid. Reverting for a moment to the illustration of adding sugar to tea, if a cup of tea in which some sugar has been dissolved were frozen, that part of the sugar which had not dropped to the bottom of the cup when the tea was cooled down would be in a state of "solid solution." I trust I have made that point clear, so that we may understand each other later. It may also be remembered that Carpenter and Keeling have proved that, beginning with pure iron, there is a lowering of the melting point (and also of the setting or freezing point) with every addition of carbon. It follows that cast irons with low total carbon have a higher melting point than irons with normal carbon, say 3.5 per cent. to 3.75 per cent.

Conditions Affecting the Amount of Carbon Dissolved in Iron.

In a blast furnace, carbon must always be largely in excess of the amount required for combustion. The excess required is partly utilised for the purpose of changing the oxide of iron into metallic iron, and also of impregnating this iron with carbon. Were it not so impregnated with the amount of carbon we are acquainted with, it would not be cast iron at all. It will be observed that I have not mentioned the reduction of manganese, silicon, etc., from their oxides, as these at present do not come into the argument. Some of the excess carbon, either as carbonaceous gas or solid carbon, effects the reduction of these oxides just as it does in the case of oxide of iron. Oxides are said to be "reduced" when they have been changed into a metallic form by being made to part with the oxygen with which they were combined. The change of the oxide of iron into the metallic form having taken place, the amount of carbon which the iron will take up is very largely conditioned by the temperature of the blast furnace. That is, the higher the temperature of the furnace, and of the iron, the more carbon will be taken up. This may go on until one of two things takes place. Either the iron becomes saturated at 4.3 per cent. carbon, or too much silicon has been reduced by the excessive temperature, with the result that the silicon, if present to the amount of 4 to 5 per cent., lowers the power of the iron to absorb carbon even at these high temperatures. It may be said, however, that under normal conditions of the blast furnace the percentage of carbon in the iron is dependent on the temperature. In cold-blast furnace practice, seeing the working temperature is low in the furnace, it follows that the power of the iron to dissolve carbon is also low. Hence it is that it is only in these irons, or hot-blast irons specially treated, do we usually find the carbon 3 per cent. and under.

The percentage of carbon has an important effect on the strength of the iron. This is partly a mechanical effect, the lines of cleavage being less in number in an iron low in carbon. There is also produced in cold-blast furnace practice a structure of iron which is partly independent of the carbon contents. Some Swedish furnaces, as stated by Swinden, by increasing the amount of blast, lowered the quality of the iron, although the analysis was unchanged. The important investigation by Cook and Hailstone bearing on a similar subject will be fresh in your memory, and of this we hope, and no doubt will, hear more. We must, however, leave aside this question of structure due to causes very imperfectly understood, indeed practically unknown, and give some attention to causes at least partly known and understood. Carpenter and Keeling proved, as already mentioned, that as the quantity of carbon increases so does the melting temperature decrease. It is to be noted that these results were obtained with pure iron and carbon only, and the melting points are in each case somewhat higher than what would obtain were the usual quantities of sulphur, phosphorus, etc., present, as in ordinary cast iron. In other words, the presence of what we may consider as impurities results in a lowering of the melting point.

It follows, then, that Swedish or other cold-blast iron low in carbon, or a hematite, which necessarily is low in phosphorus, has a higher melting point than irons which have more carbon or phosphorus. When we come to melt the former in the cupola, we necessarily increase the quantity of coke. It is to call attention to the effect of the use of too much coke that principally this Paper is submitted to your consideration.

When melting is taking place there should be a balance betwixt the quantity of air supplied and the coke burned. The theoretical quantity of coke required to melt one ton of iron is 83 lbs., this coke having carbon 93.44 per cent. (Sharp). Were 1 lb.

of this coke burned perfectly to carbon di-oxide (CO_2 the air required would equal 142.8 cubic feet, weighing 10.87 lbs., or almost 11 lbs. of air to burn perfectly 1 lb. of coke. The theoretical amount of coke to melt one ton of iron need not interest us particularly, seeing the cupola itself absorbs a large quantity of heat, and there is much heat used in the formation of the slag. The heating of the cupola, the formation and liquefaction of the slag, and the heat lost up the cupola stack are constants which obtain whatever the iron melted may be. So also is the amount of air required to burn the coke perfectly, a constant, and of the most practical character. It follows, then, that in the case of irons low in carbon, or irons having a close structure, and these are used principally in tested work, it is important that the proper balance of coke and air should still obtain. If coke be added in excess with a view to making sure that the iron will melt hot, then some of the excess carbon will go into the iron. It has been already mentioned that iron is fully charged and saturated with carbon when 4.3 per cent. is present. If the melted and melting iron is in contact with excessive free carbon, it is only to be expected that it will take up more carbon seeing it has a capacity for more, being not yet fully saturated.

I am certain that from this cause arises much disappointment to founders. They buy expensive irons and weaken them by injudicious cupola practice. The same applies to the melting of close irons for tested work. Close irons are charged with soft blast, and excessive coke, carbon is absorbed by the iron, with the result that an open grain is developed. If test bars are tried they break at low stresses, or if the castings are subjected to pressure leaking takes place at ribs or flanges. If the iron of a casting differs materially from the iron or irons from which it has been made, it is safe to conclude that the melting conditions have made an alteration.

So far as is possible, endeavour should be made only to *melt* the iron, not *change* it also. It has long been recognised that one can harden iron by over-blowing. Recent experiences have shown me that softening back by deficient blast and excessive coke is more common. When the castings may simply be soft, there is not much harm done, and may be an advantage, but where tests are required, either on the testing machine or by pressure, this softening back is fatal to good results. The author has seen curious results follow excessive carbonisation even with common irons. The iron when melted had so much carbon dissolved in it, that as soon as the metal entered the mould it cooled somewhat, and not being able to keep such a large amount of carbon still dissolved, some of it came out as "kish." The result was that the iron would not run to the other side of the mould. A sample of the casting was sent to him, with the information that although more coke had been used in the cupola the result was worse and the iron less fluid. The sample told its own story of excessive coke in the cupola. So soon as the coke was reduced to a normal amount, the metal was not only hot, but fluid. In another case a close No. 4 pig-iron, with 1.4 per cent. silicon, was so softened back as to present a very open granular iron, in a section 1¼ in. thick. Enquiry elicited the fact that here again deficient blast and excessive coke were the causes. If one wants to soften iron the procedure is right, but speaking generally as to what is the usual requirement, we want out of the cupola the quality and characteristics of the iron we put in.

We may now consider, very shortly, what may be done to lower the percentage of carbon in the iron when it is considered desirable that that should be done. I am assuming that the melting conditions are normal, that is, that it is desired to simply melt the iron, not change it. If we desire to lessen the carbon by excessive blast (the converse of what we have been considering), then we must take account of some results which would follow. We would probably oxidise silicon, manganese and iron, as well as carbon, and the product would readily be a variable one from day to day, unless with very careful control.

The use of steel for the lowering of the carbon content is a growing practice, but I find very varied opinions as regards its success. There are some readers of this paper who are more competent than the author is to deal with this matter of additions of steel. It is hoped that a full discussion will follow on this important point, and a comparison of methods of charging the steel and the percentage charges into the cupola, will be valuable. One founder uses gits and runners from the steel foundry, another uses punchings, another plate scrap. Some say they have no bother from "hard spotting," others have given up the use of steel on that account. One has difficulty in melting the steel, and yet another melts 10 per cent. of steel in a cupola with only one tuyere and gets good results. Where the material can be readily got, I understand that steel gits and runners are more readily melted than plate scrap. The latter has been rolled and densified, and will be less readily melted on that account. Plate scrap is better than punchings. The plate steel will lie on the top of the bed of coke until it is either melted or burnt (oxidised). Punchings may have part melted and part drop unmelted to the bottom of the cupola through the spaces betwixt the lumps of coke. That this can readily happen will be apparent to anyone who has watched the change and movement in the coke bed as melting is taking place. This partially-melted steel which has dropped to the bottom of the cupola is, I believe, the cause of the "hard spotting." Once it is at the bottom of the cupola, there is not heat enough to melt it. It can only be melted or dissolved by the "washing" effect of iron running over it. It is thus quite possible to have spots of steel in an iron casting if the melting conditions are wrong. It is obvious that for low carbon mixtures a cupola having a receiver is best, seeing that as soon as melted the iron runs away from contact with the coke.

Next to a receiver, the cupola with a low bed of coke will give better results than with a high bed, measuring from the bottom of the cupola to the tuyeres. It is to be remembered that melted metal does not get hotter by being kept in the cupola in contact with the coke. The heat and fluidity is obtained only in the melting zone. In short, the melted metal in the cupola is hotter than the coke with which it is lying in contact.

Whether one wants to alter the carbon content of the iron being melted, or does not want to alter it, there must be a due recognition of the conditions prevailing to produce either effect. The burning of the coke by the oxygen of the air blown in is, after all, a chemical combination of carbon and oxygen, with the result that heat is produced. Like almost all other chemical combinations, a definite quantity of oxygen combines with a definite quantity of carbon to produce complete combustion. If there is excess of carbon as compared with the oxygen blown into the cupola, then the excess carbon is present in an incandescent condition ready to be used and absorbed by the melted iron up to the saturation point of carbon in iron. On the other hand, if the supply of coke is lean, and an excess of oxygen is present, this excess of oxygen is ready to do active work, and does it. If there is no free carbon in the form of coke for the oxygen to combine with, then it will combine with the carbon content.

Bessemer steel practice shows that the air oxidises the silicon, manganese, and carbon before oxidising the iron, and we may take it that that holds good in

cupola practice. It will at once be apparent that there must be a balance betwixt coke charged and air blown in, if metal is to be simply melted and not altered in character either by softening or hardening. There is no doubt that that is so, but what is that balance of coke and air? The only reply I can give is to ask each one who hears me, or reads this paper, to try to ascertain it for himself with his own cupola and under his own special conditions. Quacks, for 1s. 1½d., Government stamp included, will give you a "cure-all," but I know of no such in foundry operations, no matter what the price might be. Each man must and ought to ascertain for himself what are his exact melting conditions. To help to this end it should be mentioned that almost invariably the foundry men who get the best results mechanically and otherwise, use the least coke.

I shall conclude by referring shortly to the function of steel in affecting the carbon contents of the iron of which it forms part when melted. The carbon in Siemen's steel with range from 0.2 to 0.4 per cent. The other elements we neglect for the present as not affecting the general result. If we mix, say, 10 per cent. of this steel to a mixture of iron containing, say, 3.5 per cent. total carbon, the result will be somewhat as follows:—

10 *Per Cent. of Steel.*

Cwts.		Total carbon. Per cent.	Carbon units
9	iron	3.5	31.5
1	steel	0.4	0.4
10			10) 31.9
		Total carbon per cent.	3.19

15 *Per Cent. of Steel.*

Cwts.		Total carbon. Per cent.	Carbon units.
8½	iron	3.5	29.75
1½	steel	0.4	0.6
10			10) 30.35
		Total carbon per cent.	3.035

20 *Per Cent. of Steel.*

Cwts.		Total carbon. Per cent.	Carbon units.
8	iron	3.5	28.0
2	steel	0.4	0.8
10			10) 28.8
		Total carbon per cent.	2.88

45 *Per Cent. of Steel.*

Cwts.		Total carbon. Per cent.	Carbon units.
5½	iron	3.5	19.25
4½	steel	0.4	1.80
10			10) 21 05
		Total carbon per cent.	2.105

These figures assume that all the steel has been melted, and that the carbon has neither been subtracted from nor added to. The author has been assured that this 45 per cent. steel mixture has been melted and cast successfully. It is obvious that with the power grey iron has to absorb carbon up to 4.3 per cent., if such mixtures are made with the object of having low total carbon in the product, then there must be as little excess coke used in the cupola as possible, consistent with hot melting.

From what has been said we may make the following deductions:—

(1) Iron may have the percentage of carbon lessened by having a greater proportion of blast to coke charged.

(2) That it is possible, by having the coke in excess, to soften back and enlarge the structure or grain of an iron which was of a close grade when charged.

(3) That in the majority of cases it is advisable simply to melt the iron, not change it in the cupola.

(4) That many failures and disappointments ensue from changes unexpected and unknown taking place in the cupola during melting.

(5) That in view of Cook's experiments and the considerations now made, it is desirable that each founder should have the means at his disposal by which he may vary the amount and pressure of blast.

One could follow the subject of carbon control through the various conditions of cooling, contents of sulphur, and other elements, but that is a subject big enough for a paper by itself. The Author meant to deal with the question of *condition* of the carbon, as well as the quantity, but this must be reserved for a future occasion.

(*For discussion on this Paper see page* 513.)

Warping in Castings of a Channel Section.

By R. R. McGowan.

The warping of castings is a subject of much interest to foundrymen, and the following notes are brought together, not so much with the intention of giving information, as of seeking information.

Warping in castings is caused by a want of balance in the rate of cooling. What are the actions to which a casting is subject as the result of unequal cooling? Every foundryman knows that warping takes place on certain castings which are subject to unequal contraction, resulting from a want of balance in the rate of cooling, and in some cases fracture.

It may not be without interest to enquire briefly as to the cause of this warping, and try to deduce from our reasoning its source, from a scientific point of view. A good example which may lead to the solution of this problem is to be found in the actions which take place on casting two square bars of iron, one say ½ in. square in section, the other 3 in. square, and each measuring, say, 36 in. in length. If these two bars be cast at the same time and under the same conditions, the smaller bar, when cold, will be found to be shorter in length than the heavier bar. The reason for this is that in the case of the light bar the rate of cooling is equal throughout, in which respect it differs from the heavier bar, the rate of cooling of the latter being unequal.

To prove the cause of this variation in length we must at this point consider another factor in the problem, viz., the question of shrinkage and contraction; shrinkage being that action which takes place in metals before solidification, and contraction that action which takes place after solidification. In the case of the light bar, these two actions, shrinkage and contraction, occur separately, whereas at one stage in the heavier bar they occur simultaneously, and when the process of shrinkage has

been completed, we have contraction acting at varying strengths caused by the metal being at different temperatures at different parts.

Let us examine the different actions which take place on the bar of heavy section. First, the metal is poured into the mould, and then shrinkage takes place in the fluid metal, i.e., the particles or crystals arrange and build themselves into their respective positions as the metal cools. Naturally this cooling first takes place on the outer surfaces of the casting, and in a thick casting it is possible to have the surfaces in a solid state, while the metal at the centre is still in liquid form. When this condition of things exist, the metal in the casting is at different temperatures, the liquid portion, of course, being at a higher temperature than that which has already set. This variation of temperature goes on until the

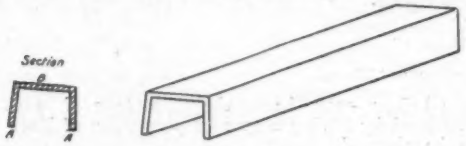


FIG. 1.

whole casting finally reaches the temperature of the atmosphere, that part of the casting which was last to solidify being the last to cool. If this difference in the rate of cooling be borne in mind, it can be determined why the heavy bar, previously referred to, does not contract to the same extent as the lighter bar; and by a similar line of reasoning can be traced the actions tending to produce warping which occur in a casting of a channel section.

As already stated, the surfaces of the metal in a heavy casting start first to cool. Now, these surfaces cannot contract to their full extent on account of the resistance of the metal at the centre of the casting, which is still in liquid form, and which might be said to be still "pattern length"; but the sides which have started to cool are trying to get to what might be termed "casting length." As this contest of forces proceeds, and a decision of some kind must be arrived at, a compromise is arranged, with the result that the surfaces which cooled first relinquish some of their contraction, and set in a state which might be called "stretched." Now, the metal in the centre of the casting which

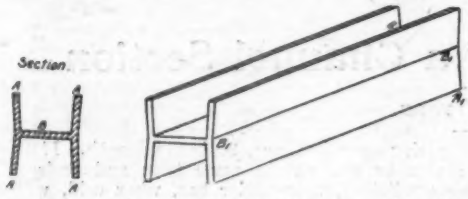


FIG. 2.

was in a liquid state and at full pattern length sets, and endeavours to contract to "casting length," but it in turn is held by the surfaces which have now exhausted their contraction. Therefore, the metal at the centre of the casting cannot contract to its full extent, with the result that it also finally sets in a stretched condition. The actions just described might briefly be summed up as follows:—The metal at the centre of the casting prevented the full contraction of the surfaces, and the surfaces in turn prevented the full contraction of the metal at the centre, therefore preventing the casting as a whole from contracting to its full or natural extent.

In the case of the bar of light section this variation of temperature in the casting, causing the double pulling action, does not occur, as the whole casting cools off at the same rate, and therefore allows the lighter casting to contract to its full extent.

Let us now examine the actions which cause warping in casting of a channel section. Fig. 1 illustrates the casting under consideration, which is of equal metal throughout, but in which warping takes place.

If it were possible to develop this section into a flat plate, it would be found that the edges of the plate were the first to cool, and the centre of the plate cooled at a later stage—hence the difficulty in casting a truly flat plate. The point of importance at the moment, however, is that the edges cool first. The actions causing the warping of a channel-sectioned casting may be made clearer if the section with two additional flanges, making the channel into an "H" section (see Fig. 2) is first considered.

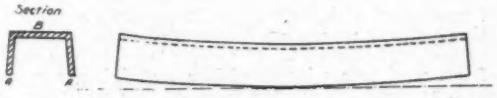


FIG. 3.

In the casting the edges A cool first, but as the part B does not cool until a later stage, these edges A on the full length of the casting set "stretched," and as the edges A started to cool first, they will have exhausted their contraction before the surface B.

Now, if there had not been an equal force acting on either side of B the length between B^1 and B^1 would have been shorter than the length A^1 to A^1. It will be noted that in the case of the heavy bar and the H-section casting, the part last to cool was at a point equidistant from the parts which cooled first, therefore, the forces acting were exactly balanced, and a straight casting is the result. But in the case of the channel section, Fig. 1, the forces acting are unbalanced, and the result is a warped casting. There is in the channel section nothing to prevent the surface B from contracting to its full extent, as the two upper flanges which balanced the forces have been removed; therefore, the total length of the surface B is shorter than the length

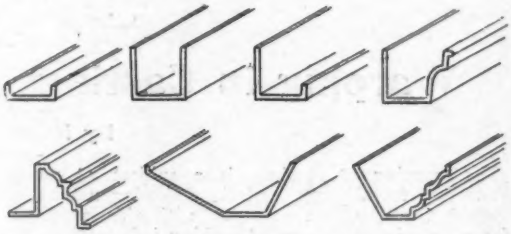


FIG. 4.

of the edges marked A, and the result is that from a straight pattern we get a warped casting, as shown in Fig. 3.

Against this warping the pattern-maker must embody in the pattern sufficient camber in an opposite direction, in order that the work, when cast, may turn out straight. To determine exactly the direction and amount of camber to allow on patterns requiring treatment in this manner, is a matter of great difficulty; reliable data upon the subject is anxiously awaited by the practical workman.

(*For discussion on this Paper see page* 514.)

Metallography as an Aid to the Iron-Founder.

By John S. G. Primrose, A.G.T.C., A.I.M.M., (Metallurgical Department, Glasgow Technical College).

One of the most useful applications of scientific principles to foundry work is the investigation of failures, and whilst a trained chemist is in many cases found to be of great service in this respect, he is not, as a rule, able to do more than indicate the percentage of certain elements present in the metal. He is not in a position to say in what way these are arranged or combined in the casting, nor can he state the treatment to which the metal has been subjected, except in very rare instances. When anything goes wrong the moulder almost invariably blames the metal, but much more frequently the fault is attributable to the incorrect manipulation it receives, or else to the selection of a mixture unsuited for the purpose to which it is put.

What is of supreme importance is to determine the internal structure of the cast metal, and whilst in iron castings the fracture more often conceals than reveals this, the microscopical investigation of the metal is a useful aid in determining the cause of serious irregularities. This method of examining a polished surface of the metal is now sufficiently well known, and need not be minutely described here, but it is regrettable that this most valuable aid to the methods of proximate analysis has been left so long in the hands of purely scientific investigators. They are, no doubt, partly to blame for having introduced a somewhat elaborate phraseology and also for advancing theories often considerably at variance with one another, and thus obscuring from the practical worker the great advantages to be gained by this most modern method of physical analysis. Metallography has emerged from the stage of theorising and distrust, and is now being employed systematically in many metal works, particularly with great benefit in foundries, not only abroad, where it was first appreciated, but also to a considerable extent in this country.

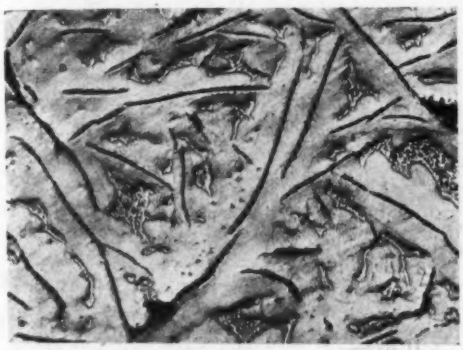


FIG. 1.—FRACTURED CYLINDER. MAG: 60 DIAM.

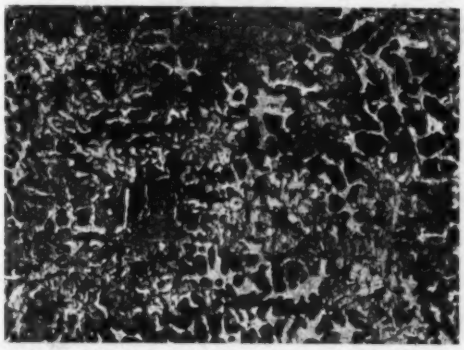


FIG. 2.—CYLINDER TEST BAR. MAG 60 DIAM.

It cannot be expected that everyone engaged in iron-founding should become an expert metallographer, but it is certainly advisable nowadays that those chiefly concerned in the production of sound castings should have a sufficient acquaintance with the methods of application and the conclusions it can show. This knowledge would, at least, enable them to understand and benefit from the report of a trained man who is capable, with a little practice, of applying this test, which more accurately than any other shows the chief constituents of the metal and, what is more important, their relative sizes and mode of

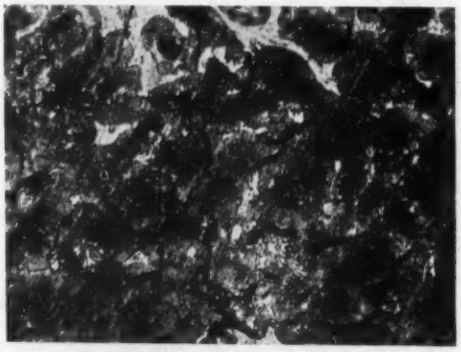


FIG. 3.—OPEN-GRAIN IRON. MAG: 90 DIAM.

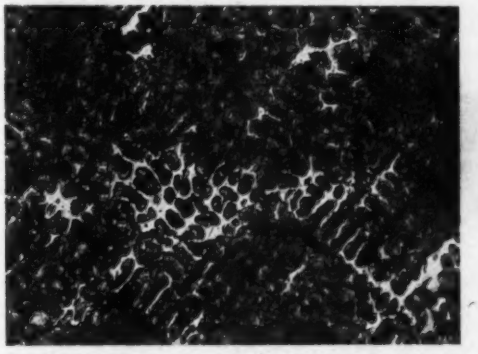


FIG. 4.—CLOSE-GRAIN AL. IRON. MAG: 90 DIAM

arrangement in the casting. It has to be admitted that metallography has certain limitations, and can never be made to replace chemical analysis, to which, however, it is a serviceable adjunct by locating constituents which the analysis only detects. The microscopical examination has several advantages over the chemical investigation; it can be much more rapidly performed, it can be applied to the material without destroying, or even injuring it, and inspection can be carried out on the actual place of failure or on portions of the metal much too small for analysis.

Method of Work.

Care must be taken in the selection and preparation of the sample for microscopical examination, and particularly in the case of a failure to be investigated. If possible the fracture should be preserved and kept free from dirt and rust, which soon disguises its appearance, and sections should be cut from the metal, not only at the face, but also a short distance from the point of fracture, for the sake of comparison. These small pieces can then be polished and examined under a fixed microscope, but it is equally feasible to polish a portion of the metal in its position and bring a portable microscope over it for the examination. The polishing should leave the section to be inspected perfectly plane or level, and as free from scratches as possible. It is best to look at the polished surface first of all illuminated by the light falling obliquely upon it, since this at once shows the presence of any serious scratches, but if these are not too deep or too numerous it is not essential to spend time in removing them, unless a photograph is desired.

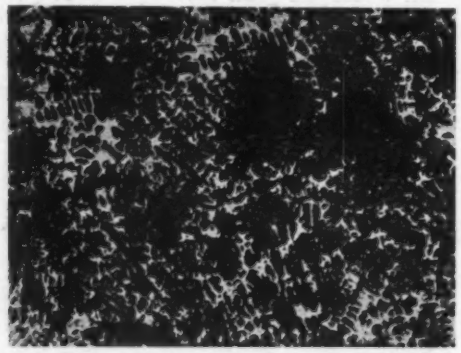


FIG. 5.—CAST-IRON PIPE, CHILLED. MAG: 60 DIAM.

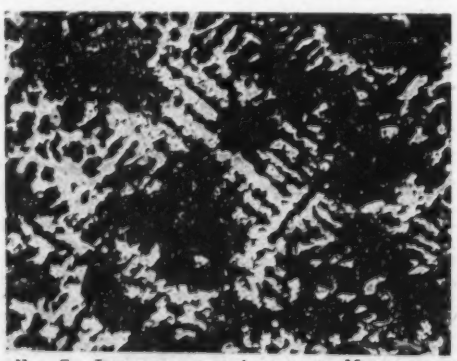


FIG. 7.—INCOMPLETELY ANNEALED MALLEABLE CASTING. MAG: 120 DIAM.

The examination is then continued by vertical illumination, which is accomplished by means of a special fitting in the tube of the metallurgical microscope. It consists of a small prism, or even a cover glass will do, and this reflects the beam of light vertically on to the metal surface, which in turn sends sufficient light back through the objective and eyepiece to make the structure visible. This preliminary view of the metal after what is known as the polish attack, and before any etching in acid has been done, is most serviceable in the examination of cast iron. The harder parts stand out in relief, and show brightly illuminated, the softer constituents are partly rubbed down and may show slight colouration, and the flakes of graphite and any minute patches of very hard material get broken down and crumble out, leaving dark lines and areas. The location of any small blowholes or similar irregularities is clearly seen, and then the specimen is etched, usually with a very dilute solution of acid (preferably nitric acid) in alcohol. This is to "develop" the structure, or show up the different constituents more clearly, and it is specially valuable in showing the arrangement of the combined carbon in cast iron, and also for locating the sulphide and phosphide combinations. Instead of acid etching, very fine colour effects are observed on gently heating the polished specimen, when the phosphoric portions become differently tinted by the oxidation.

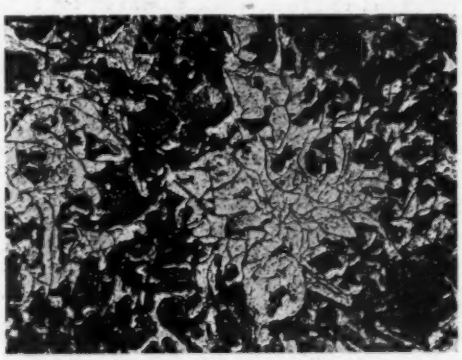


FIG. 6.—CAST-IRON PIPE (1847). MAG: 60 DIAM.

FIG. 8.—GOOD MALLEABLE CASTING. MAG: 120 DIAM.

Investigation of Failures and Faults.

The chief micrographical constituents of iron and steel have been fully described and illustrated in several text books and scientific papers on different

divisions of metallography; but these, as a rule, only deal with sound metal which has passed through normal or even ideal conditions. This information undoubtedly serves as a useful standard for comparison, but generally very little is said on the subject of wasters and the appearance under the microscope of metal which has shown serious defects. The main object of this Paper is to record a few examples of "something gone wrong," which have come under the writer's notice, and to indicate how easily a little experience in comparing good and bad structures gives the clue to the cause of trouble. On ascertaining this, it is not a very serious matter to see the right direction to take in order to obviate or minimise the chance of a recurrence.

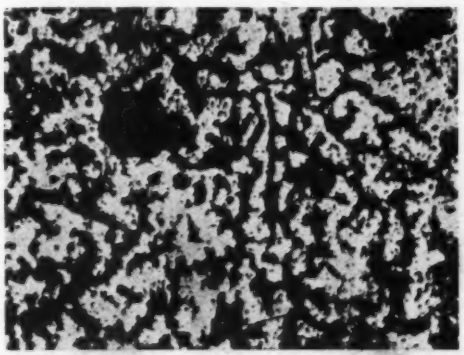


FIG. 9.—BURNT FIRE BAR. MAG: 120 DIAM.

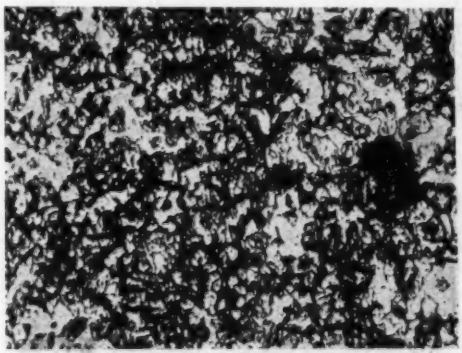


FIG. 10.—NORMAL FIRE BAR. MAG: 120 DIAM.

A heavy casting failed in service, although the test-bar of the metal had given quite satisfactory results. A comparison of the micrographs of samples of each is shown in Figs. 1 and 2, and clearly demonstrates the cause as having been due to the use of too rich an iron mixture, since the high silicon present had been able during the slow cooling to eject a large proportion of the carbon as graphite. This constituent has separated out into very weak and much elongated straight flakes (black) Fig. 1, and thus the phosphide of iron eutectic portions have been split up into segregations, or little detached patches showing like islets throughout the mass. This specimen has only been very lightly etched so that the ground mass (white) does not show up the pearlite clearly distinguished from the silicon-ferrite, as a deeper etching would do. Fig. 2 shows a photomicrograph of the metal in the test-bar, a little more deeply etched, but photographed at the same magnification of 60 diameters. In this the strongly interlocking network of phosphide (white) is seen finely distributed around the pearlite areas (dark), throughout which the graphite is separated in strong, curved flakes of small size. This shows clearly how little reliance can be placed on tensile and similar physical tests of sample bars, especially if the casting is a heavy one with considerably greater thickness at certain portions. Obviously the wrong class of metal was here used, and a preliminary test, such as Keep's shrinkage, would have obviated what was a serious financial loss.

It is not always possible to physically hasten the cooling of a large mass of cast iron sufficiently to prevent the silicon from "softening" it dangerously by precipitating the greater part of the carbon into the graphite form, but it is often feasible to do so by chemical means. Stripping off the flasks before the castings are quite cold is permissible with small jobs to effect this end, but it is not always possible or applicable to heavy castings, in which case a little aluminium powder or ferro-alloy may be advantageously added to the ladle. The effect of this is to close the grain of the metal in a most remarkable way, as shown by reference to Figs. 3 and 4. The former is the photomicrograph of a medium strong cast iron from a test-bar cast in the usual way, but judged to be rather open in texture for the purpose desired. The structure is fairly satisfactory, showing only moderately large flakes of graphite embedded in pearlite (dark areas), with irregular isolated patches of the iron phosphide segregations (white). Fig. 4 shows the very much finer grain resulting from the addition of only one quarter of an ounce of aluminium to about 2 cwts. of iron in the ladle. The second

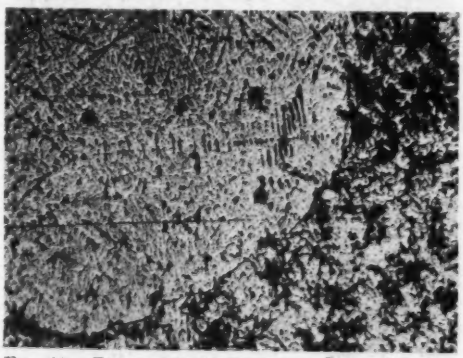


FIG. 11.—PHOSPHIDE GLOBULE IN GREY CASTING. MAG: 30 DIAM.

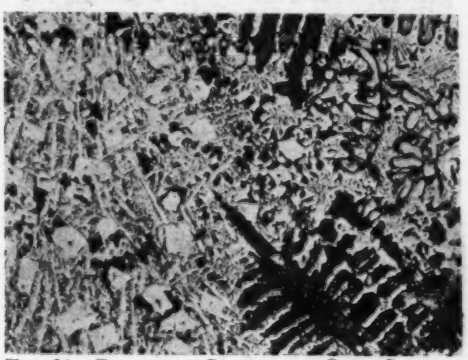


FIG. 12.—PHOSPHIDE GLOBULE IN GREY CASTING. MAG: 90 DIAM.

test-bar was cast from the same ladle and at the same temperature as the first, immediately after stirring in the aluminium, and the photomicrograph, taken at the same magnification as Fig. 3, shows that besides the graphite flakes being much smaller, the phosphide eutectic (white) has assumed an almost continuous meshwork formation. Any means which produces this effect results in the strengthening of the iron, and evidently the trace of aluminium has done this by slightly accelerating the rate of crystal growth during cooling, as well as aiding the silicon present in separating sufficient graphite to keep the metal grey. In this instance it was easily possible to forecast from the micro-structure which was the stronger material, and in testing, the aluminium-treated bar showed a transverse strength of 34 cwts., as against 24 cwts. in the first test-bar; the deflection was raised from 0.12 in. to 0.16 in., and the tensile strength was also considerably augmented.

FIG. 13.—SULPHURY WHITE IRON. MAG: 120 DIAM.

Too severe hastening of the rate of cooling is a source of trouble even with grey-iron castings, because, particularly in thin sections, chilling is apt to result, and this may make the metal almost white, in which state it is very brittle, and develops high shrinkage. Fig. 5 is the photomicrograph of the interior of a cast-iron pipe which failed badly in testing, and showed a most peculiar marking on the fractured surface. Evidently the cooling had been so rapid as to leave the greater portion of the metal white, or rich in cementite, the white portions. In the inner portion the shrinkage had resulted in several shrink holes (shown black), and although a portion of the metal was pearlitic, yet these areas were completely surrounded by the brittle cementite. To compare this with a good pipe structure Fig. 6 is reproduced. It is a section from a cast-iron water pipe laid in 1847, and only recently scrapped, and the micrograph shows the (black) graphite separated in well-curved flakes throughout the silicon-ferrite ground mass (white), the pearlite (dark areas) being well distributed.

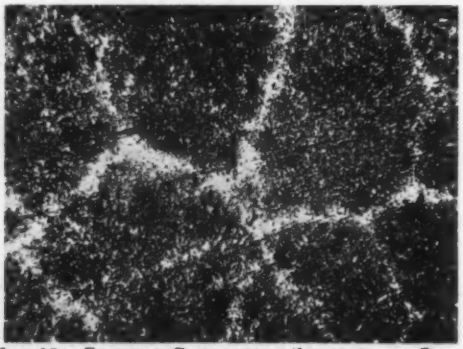


FIG. 15.—GLOBULE CONTAINING SULPHIDE OF IRON. MAG: 30 DIAM.

Heat Treatment of Cast Iron.

This is a matter which until recently has not received much attention, unless in the manufacture of malleable castings. These are produced on suitably annealing white iron until the brittleness due to the cementite, has been removed, and excess carbon which has not escaped is left in small amorphous patches, which do not give rise to fracture, as does graphite. Malleable castings, however, sometimes show brittleness unexpectedly, and then the microscope can readily reveal the cause. The sample shown in the photomicrograph, Fig. 7, was taken from a set of brackets which failed signally when put under moderate stress, and the reason was not far to seek. The structure shows a considerable portion of cementite (white) left undecomposed, and surrounding the dark pearlite areas. Only a very little temper or amorphous carbon had been separated, and obviously the annealing had not been sufficient, either in duration, or in temperature attained. The structure, in fact, resembles that of a mottled casting, and the fracture was distinctly grey. Fig. 8 shows a micrograph of a properly malleablised casting; the white ground mass is ferrite low in silicon, the pearlite is well laminated and evenly distributed, and the irregular black patches show the small areas of temper carbon.

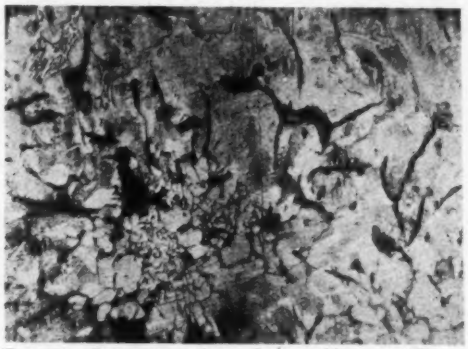


FIG. 14.—SULPHURY GREY IRON. MAG: 120 DIAM.

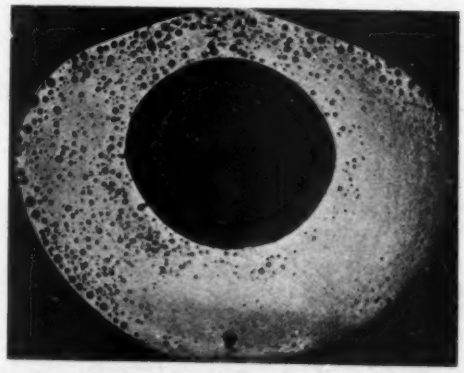


FIG. 16.—POROUS CASTING WITH BLOWHOLES.

Grey iron, also, undergoes considerable change when subjected to heat treatment, and one of the most remarkable results is the enormous growth, sometimes amounting to over 35 per cent., caused by repeatedly heating most grey iron castings. The main cause of this has been explained as being due to the disintegration of the material by the oxidation of the iron silicide (or silicon-ferrite) to a mixture of iron oxide and silica; this also increases the weight of the casting, although a considerable portion of the carbon may also be burnt off. Fig. 9 shows the photomicrograph of a bar from a cast-iron grid, which had become so brittle, after about 200 reheatings, that a push with a poker broke it. The continuous network of iron oxide and silica (dark) is very clearly sufficient to destroy all tenacity originally possessed by the metal, and evidently gas holes have also been formed. For comparison, Fig. 10 shows the structure of the normal fire bar, which, although grey, evidently carried a considerable portion of cementite (white), cutting up the pearlite areas in which the graphite is separated. The solution of this trouble is not quite so clear, but recent experiments by Carpenter have shown that manganese is the key to the situation, since by reducing the silicon content of the iron to about 0.5 per cent., the carbon to 1.5 per cent., and raising the manganese to about 1.5 per cent., metal is obtained which stands very repeated reheating without any growth. Metal of this composition is nearly white, and might almost be regarded as semi-steel, but it is said to machine quite easily, and it increases in strength by reheating; the microstructure shows it to be a refined cast iron.

Phosphide and Sulphide Shot.

When a casting has to be machined in manufacture, the iron used needs to be low in sulphur and not too high in phosphorus. Both of these elements form compounds with iron which are very hard and brittle; they also have lower melting points than the metal, and thus collect into balls or irregular masses, which, as they solidify last, are called eutectics. Iron sulphide is fortunately not often present, as it would form a mesh-work round the iron crystallites and make the metal very hard, but at the same time excessively brittle. Iron phosphide is much more frequently encountered, and the chief difficulty with it is the persistent manner in which it separates as shot and globules, either firmly bedded into the metal or often apparently extruded from the surrounding mass into some gas cavity near the centre of the casting. They are exceedingly hard, and can take the cutting edge off a tool quite readily; even chipping them out can blunt a chisel repeatedly. If small, or if only slightly adherent to the metal, they may crumble or break away under the action of the tool, and leave a cavity or pit hole which is often a serious defect. Fig. 11 shows a photomicrograph of a phosphide globule at a low magnification (30 diameters), in which the difference of its structure from that of the surrounding iron is well marked.

The dendritic cross bar structure of the pearlite (dark) is characteristic, as are also the long white needles of iron phosphide interpenetrating the globule in all directions. These needles are rectangular in section, as shown in Fig. 12, which is a photomicrograph of another globule taken at a higher magnification (90 diameters), and showing the inter-crystalline eutectic of iron phosphide with the silicon-ferrite in presence of the carbide of iron.

Judging from the extreme hardness of these "bullets," as they are sometimes termed, it is frequently asserted that they are due to chilled metal, either due to bad pouring or to slight spluttering in the gate if not properly constructed with a well; but the writer has found from the microscopical examination of a large number of instances, that the fault is almost always due to phosphide segregations even in grey iron mixtures. It is not necessary that the whole globule be of highly phosphoric iron to get a segregate, since in a number of instances in which the globule was almost detached from the sides of the cavity, only the skin of both shot and pit showed the phosphide eutectic. It would, therefore, appear probable that on hot phosphoric metal being allowed to stand cooling, aggregates of the phosphide may form films round small portions of the metal, which are thus enclosed as bubbles, and although the metal inside may be of nearly the same composition as that around it, the separating film of phosphide alters its structure considerably, even to the extent of leaving it as a hard, white spot. The shrinkage of such a globule being greater than the surrounding grey metal, it is capable of forming a cavity, the envelope of which was originally the separating film. It is not possible that all globules are formed in this way, as the process may be reversed, and into the already formed gas cavity liquid phosphide or phosphide eutectic iron may be intruded.

The difficulty is most readily removed by the use of a less phosphoric mixture of irons, although by having the ladle metal well stirred before pouring, and not too hot when poured into a casting with heavy sections, the trouble can also be got rid of.

Although sulphide of iron is not often got in cast iron, any sulphur which is present is usually rendered almost harmless by the manganese in the metal. This is usually sufficient in quantity to form the sulphide of manganese, and this either rises into the slag, or, if entrapped in the metal, distributes itself fairly uniformly in little cubical or rectangular patches. Fig. 13 shows the arrangement of manganese sulphide (black) in a brittle sulphury white iron; the ground mass (white) of which is of iron carbide (cementite), and the pearlite is represented by the half-tone areas. In a grey iron, the sulphide does more harm, by reason of its effect on the graphite separation, see Fig. 14. This is a photomicrograph of metal from a small boiler which fractured badly. The manganese sulphide was seen as small dove-grey patches, but the striking feature of the structure near the fracture was the brittle mesh work shown in the photo. In the malleable iron casting (Fig. 8) the manganese sulphide is also visible as small grey patches, which are not seriously harmful unless segregated to one part of the metal, which is then rendered brittle.

Only one globule of iron sulphide has come under the writer's notice, and its structure is quite different from the phosphide formation, as shown in Fig. 15, which clearly shows the white sulphide mesh-work already mentioned, and the peculiar small formation of the graphite (black) and iron carbide.

Blow-Holes.

Most of the blow-holes met with in defective castings are due to some defect in moulding, either from bad venting, or—a more fruitful source—the incomplete drying of moulds and cores, which gives rise to steam. This may make the metal quite porous, as shown by the interesting example reproduced in Fig. 16, which is a slightly reduced photograph of a roughly-polished section of cast iron. It is not usually necessary to use the microscope to determine the cause of blow-holes, but the extreme value of the metallographic examination of defective castings should be more widely appreciated.

As it is often of great service to have even a partial analysis of the specimen examined microscopically, the following table is appended, and gives

the percentages of the chief elements present in those cases where the samples were large enough to permit of drillings being taken. The author has to express his indebtedness to Mr. H. S. Primrose, M.I.M., metallurgist to Messrs. G. & J. Weir, Limited, for his kind assistance with the analyses.

Specimen No.	Carbon. (combined)	Silicon.	Sulphur.	Phosphorus.
1	0.17	2.25	0.1	0.85
2	0.38	2.18		
3	0.61	1.62		
4	0.67	1.68		
5	1.68	2.34	0.165	0.033
6	0.35	2.66		
7	0.321	2.15	0.08	
8	0.55	0.72	0.15	0.02
10	0.29	1.87		
13	2.89	1.23	0.714	1.653
14	0.583	2.34	0.275	0.057

In No. 9 the silicon was nearly all present as oxide (SiO_2), and the small percentage of carbon left was in the amorphous condition. Samples Nos. 11 and 15 were too small for even partial analysis, and No. 12 was so highly segregated that the analysis could give no more than an average value to the percentage of the constituents.

(*For discussion on this Paper see page* 515.)

The Crystallisation of Cast Metals.

By Cecil H. Desch, D.Sc., Ph.D.

When a metal is melted and allowed to cool, it changes into the solid state by a process which is exactly similar to the freezing of water, or to the crystallisation of a salt from a solution. If we do not always realise this fact, it is because the process is less easy to observe in metals. We can see the crystals of ice forming on the top of a pond or a puddle, we can see the deep blue crystals forming in a solution of copper sulphate. But metals are not transparent, and the crystallisation goes on mostly out of sight, until the whole mass of the metal has become solid. There are two ways in which we can become aware that this mass is built up of crystals. We may break the metal across, when we see that the fracture presents a number of glistening faces, or we may cut the metal through and examine the cut surface with the aid of a microscope. This second way tells us much more than the first, and it is in this way that most of our knowledge of the crystallisation of metals has been obtained.

Common salt crystallises in cubes, and when a small cube has been formed, it grows by the addition of more salt on each of its sides, so that it still retains the shape of a cube. Crystals are not always formed in this way. In those beautiful crystals which make up an ordinary snowflake, the particles of ice grow in the form of a star, usually with six branches. These branches shoot out from a centre, and as they become longer they throw out shorter branches on each side, but always keeping a symmetrical form. The result is that instead of a cube or other regular solid, we have an elaborately branched skeleton. The crystals which metals form when they solidify are skeletons of this kind, only, instead of being perfectly symmetrical, like snow-crystals, which are formed in undisturbed vapour, they are always more or less distorted and one-sided. The crystallisation starts at a number of points, and if each skeleton grew equally in all directions, the solid metal would, in the end, be made up of a number of little solid masses, all similar in form. This regularity is disturbed, because the metal does not cool at an equal rate everywhere. In an ordinary casting, the metal next to the surface of the mould cools first, so that the first crystal centres are formed there, but they can only grow inwards, and the skeletons formed are always elongated in that direction. First, a long rod or central rib shoots out from the cooling surface into the mass of the liquid metal, then this rod gives off branches sideways, and these again branch, until a very complicated skeleton is formed. Such a crystal has a structure somewhat like a fir-tree, with its trunk and branches, or in other cases it reminds us rather of the fronds of a fern. As the metal becomes solid, the spaces between the branches are gradually filled up, and the structure apparently disappears. Occasionally it may happen that all the liquid metal has been used before the filling-up process is complete, and then the trunk and branches are preserved for us in their original form. This happens when considerable piping occurs. Beautifully formed "fir-tree" crystals of steel have been found in the pipes of large steel ingots, the shrinkage of the metal during cooling having left the crystal skeletons projecting into the cavity to a distance of a foot or more. Similar crystals, on a smaller scale, are common in the piped heads of castings of many metals.

Apart from such accidental occurrences as these, we can easily reveal the manner in which a casting is built up of crystals by cutting a section through it, polishing the cut surface, and attacking it by means of an acid. In most commercial metals and alloys the material which solidifies first has a different composition from that which remains longest fluid, and although the whole mass appears uniform when it is cut and polished, we find that the acid attacks it unequally, so that the original pattern is etched out and becomes visible. If we apply this process to a casting, we find the "fir-tree" structure very conspicuous, the base of the trunk being in contact with the mould, whilst the trunk itself is directed inwards towards the centre. We find also that the growth of each "tree" is limited by that of its neighbours. When the growing branch of one skeleton meets a branch of another skeleton, it ceases to grow, and a boundary, more or less irregular, is produced. This boundary is evidently the weakest place in the mass, and the strength of the metal will largely depend on the direction it takes. If the branches of neighbouring skeletons "interlock," the boundary has a zig-zag form, which assists the adhesion of the crystals to one another, but if adjoining crystals all lie in the same direction, so that the boundaries between them are nearly straight, the metal breaks along those lines as soon as it is strained. It is for this reason that square corners are avoided, for instance, in hollow castings. The crystals grow chiefly at right angles to the surfaces, and where, as at a corner, two sets of crystals meet, a sharp boundary, which is almost a straight line, is formed, and the casting easily

breaks along that line. If the corner is rounded instead of being sharp, there is a gradual change of direction of the crystal skeletons, and such lines of weakness are avoided. In chill castings, crystallisation takes place from a greater number of centres, and proceeds so rapidly that there is not time for the long skeletons to be formed, hence the crystals in such castings are smaller, and their boundaries more irregularly arranged, than in castings which have cooled slowly.

The process just described is all that occurs in the crystallisation of a pure metal, or of certain alloys, such as cast brass of the best quality. If the brass contains certain impurities, such as lead, these impurities remain liquid until everything else has solidified, and at last form little isolated masses between the crystals. The strength of the casting depends in a large measure on the arrangement of these masses. Lead in brass, for example, collects in little globules, which do not materially weaken the metal if only present in small quantity, whilst bismuth forms thin, highly brittle films between the crystals, preventing them from adhering to one another. For this reason bismuth is a far more dangerous impurity in brass than lead.

Besides such casual impurities, many alloys, and most irons, contain constituents which normally remain fluid after the greater part of the mass has solidified. Without entering into details, we may say that the part which remains longest liquid is known as the *eutectic*. Consider, for example, a grey iron containing 1 per cent. of phosphorus. The greater part of the phosphorus remains in the eutectic, and appears in a section in the form of brilliantly white patches, consisting chiefly of phosphide of iron, lying between the crystals of iron. This phosphide is hard and brittle, and contributes to the brittleness of the iron.

We may next consider a white cast iron, a material which gives some of the most beautiful of crystalline patterns when examined with the microscope. The first crystal skeletons consist of iron holding a certain quantity of carbon, as well as small quantities of other elements, in solution. These skeletons are excellent examples of the "fir-tree" type of structure. The space between their branches is filled up by the eutectic. Microscopical examination shows that this eutectic is made up of two constituents, one of which is of the same nature as the original skeletons, whilst the other is the white, exceedingly hard carbide of iron. This duplex structure is characteristic of eutectics.

Where the eutectic forms so large a proportion of the whole as in white cast iron it unites together the different crystal skeletons in a way that is obvious from an inspection of the structure.

Two points in the structure of alloys containing a eutectic are remarkably well illustrated by the example of white iron. The first is the remarkable arrangement of the two materials that make up the eutectic. It is easy to see that their particles are not distributed haphazard, but that the darker constituent forms bundles of parallel rods, which appear to the eye as groups of dots if the section happens to cut across them, or as lines if they are cut lengthwise. This parallel arrangement appears in various disguises in the most different alloys, and we can sometimes ascertain with certainty that it is governed by the direction of the main crystal skeletons. It is responsible for the great beauty of the banded structures in many eutectics. This directive power is so great that masses of eutectic may sometimes grow in such perfect parallel arrangement that they take on the form and appearance of single crystals. Certain Swedish white pig-irons high in carbon, for example, contain large flat plates which have every appearance of being true crystals, until a microscopical examination shows that they are really masses or "colonies" of eutectic grouped as just described.

The second point relates to the form of the crystal skeletons themselves. We commonly think of crystals as having characteristically sharp angles and flat faces. There are some exceptions; native diamonds, for instance, commonly have curved faces, but the rule is a general one. We see, however, that the crystal skeletons in white iron have no sharp angles, but rather present the appearance of chains of oval masses, like drops of a liquid. Such a peculiarity is by no means confined to iron, but is found in most metals and alloys. A few metals, such as bismuth and antimony, and a few of the hard and brittle compounds which metals form with one another, have sharp angles at the ends of all their branches, but these are exceptional. It would appear that when a metal is crystallising from the fluid state, two forces compete with one another in determining the form that it takes. One force, the same that produces the globular shape of drops of oil in water, or of mercury spilt on a table, tends to draw the metal into globular or oval masses, whilst the other, the crystallising or directive force, tends to group the particles in definite straight lines having certain fixed directions. The actual shape of the crystal skeletons depends on the degree to which the one force is able to overcome the other, but the conditions which govern the process are among the most obscure problems of metallurgy.

The author cannot hope that these few observations have any practical value in relation to foundry practice, but he would express his conviction that an acquaintance with the structure of cast metals—the way in which the bricks are fitted together, so to speak—is of the greatest value in any attempt to solve the difficulties which occur in respect to the strength or weakness of castings, and he would also urge that the microscope as a means of controlling foundry practice deserves more consideration than it has yet received, except in a few quarters. Rolled and worked metals are microscopically examined as a matter of routine to a rapidly increasing extent, and an extension of the practice to cast metals is in the highest degree desirable.

(*For discussion on this Paper see page* 515.)

Notes on the Treatment of Steel Castings.

By Professor A. Campion, F.I.C. (Glasgow and West of Scotland Technical College).

The following notes are presented solely for the purpose of promoting a discussion on the important subject of steel castings, and no claim of originality is made. The writer has so frequently been asked by steel founders and others interested in castings of steel, such questions as "What is the best temperature to anneal steel castings?" "What is the best form of furnace?" etc., that he considers no apology is needed for bringing forward at the present time a few notes on the points which have to be taken into account in coming to a decision as to the treatment necessary to obtain the desired results.

At the outset it must be emphatically stated that to such questions as above quoted, it is impossible to give a direct answer applicable to all cases. There is no best temperature, no one furnace, which can be universally used; these and many other factors, some of which are enumerated below, depend upon local conditions, and in order to answer such questions, one must know the local conditions and requirements. It is also to be noted that the temperature to which the material is heated, although important, is not the only factor which determines the final properties of the metal.

Amongst the more important points which have to be considered in determining the treatment necessary to obtain the best results in the final casting are :—

(1). The composition of the metal.
(2). The mass of the casting.
(3). The shape of the casting.
(4). The casting temperature.
(5). The rate of cooling in the mould.
(6). The rate at which the material is heated in the annealing process.
(7). The length of time maintained at the annealing temperature.
(8). The rate of cooling from the annealing temperature.
(9). The purpose for which the casting is required.

There are other factors, but the above list will suffice to emphasise the complexity of the subject and the difficulty of giving direct general answers to such enquiries as quoted earlier.

It may be as well at this juncture to point very distinctly to the great difference between the conditions necessary for successfully annealing cast material, and material which has been mechanically worked by forging or rolling. The general effect of the treatment is very similar in both classes of material, but in the case of the casting is much more marked, as the material is then in its most brittle and unreliable condition. The object of annealing steel is to toughen it and increase its reliability, not only by removing internal stresses which have been set up during manufacture, but also by causing the material to undergo a molecular rearrangement and recrystallisation, and thus increasing its ductility as shown by the percentages of contraction of area at fracture and of elongation, and also, as a rule, a decrease in the maximum stress which is shown in an ordinary tensile test.

In the case of rolled or forged material this molecular rearrangement and increased cohesion between the crystals is brought about as the result of the mechanical work. In the case of cast steel it is necessary to produce by heat treatment alone the changes that are brought about by work plus heat in the case of rolled or forged material.

The treatment most suitable to obtain the toughest and strongest material is not the same for all steels, that is to say, it varies considerably with the composition, and not only with the composition but also the constitution of the material. The influence of carbon on steel is universally appreciated, and it is unnecessary to enter into that subject on the present occasion beyond mentioning that the higher the carbon the greater the internal stresses which are likely to be set up during cooling, and consequently the greater the tendency of the casting to "fly" or "split" during cooling or during reheating.

Constituents other than carbon, however, have an effect upon the treatment, or perhaps it would be more correct to say that the effect of the treatment upon the steel is influenced by the presence of certain constituents: for instance sulphur or sulphides and phosphides, although present in the unannealed casting in a condition prejudicial to the strength and ductility of the material, may as the result of the heat treatment so change their form or condition as to become comparatively harmless. Sulphides are a notable example of such change. Unfortunately this desirable change in the form of sulphides does not always take place; some material persistently resists any change in its sulphide constituents by heat treatment and remains brittle and useless. This is a point requiring further investigation, and the writer considers it a question which, if investigated by some one connected with a steel foundry and the results embodied in a short paper, would prove extremely interesting and eminently suited for presentation and discussion at a future Convention. The mass and shape of the casting influence very considerably the rate of heating up, as if too rapid the outside of a large piece would be hot whilst the centre might be quite cold, and the tendency to split would be great. The shape of the casting also requires consideration; the object should be to obtain as nearly as possible every portion of the casting heated at the same rate, and to the same temperature for the same length of time. This brings one to the time element, which is too often entirely forgotten; it is astonishing how people worry about the temperature being correct within very narrow limits, and yet never give a single thought to the time factor which may in many cases be *the determining factor* for the success of the annealing process. The changes of structure and constitution taking place during annealing are not instantaneous, but take a certain period of time, which varies with the nature of the material, shape, mass and previous treatment; and unless the temperature is maintained for the necessary time the changes are not complete, and little or no improvement of the casting may result.

At the risk of being wearisome the author would therefore repeat that temperature and time must be considered together; the former is an important—very important—but not the only factor in the case.

The cooling off must be as slow as possible until all chance of chilling or change is passed, and even then the removal from the furnace must be carried out cautiously in order to prevent chilling or unequal cooling and setting up of internal stresses which would tend to reduce the strength and reliability of the material. It must be remembered that the ultimate object of the founder is to turn out a casting as tough, strong and reliable as possible, in fact to approach as nearly as possible the strength and reliability of forged steel in shapes so intricate that the cost of forging would be prohibitive.

The author trusts that these few notes, incomplete as they are, may assist to a better understanding of the intricate nature of the problems connected with the annealing of steel castings, and lead those who are every day engaged in the production of such materials to realise that local conditions must be studied, and that no one simple rule can be given which will apply to all cases; in fact, there is no short cut to success in the annealing department of a steel foundry.

(*For discussion on this Paper see page* 517.)

Special Foundry Pig-Iron.

By Herbert Pilkington, M.Inst.C.E.

This brief Paper makes no pretension to be any other than a suggestive one. It may seem here in Scotland to be a somewhat bold thing to go into such a question, in a country where so many excellent special foundry pig-irons are made; but to prevent any misunderstanding at the outset, this Paper does not deal with soft foundry irons at all, but is prompted by the thought that we cannot but be impressed by the fact that although there is a very greatly decreased production in England of cold-blast and hot-blast pig-irons made from clay-band ores for the most part, there is also a very greatly increased demand under modern conditions for strong pig-iron suitable for cylinders, rolls, and many other strong and sound high-class work which requires a close, dense, strong and sound pig-iron of high tensile strength.

To a large extent this demand has been met in a way by the manufacture of what the writer chooses to call "artificial pig-iron," that is to say, iron which has been re-melted and refined, or made by a process which is supposed to refine. The stock materials used for this purpose for the most part are old ingot moulds—which are made from hematite, as you are aware—old rolls and many other sorts of old materials which are blended and mixed with perhaps a little refresher in the way of good hematite pig-iron, ferro-manganese or spiegel as the case may be. These are manipulated to produce a certain supposed ideal composition of iron for the purpose for which it is required. Much of this class of iron is imported.

The writer ventures to say that the iron resulting from these blended products, many of which are burned, is in no sense a satisfactory substitute for the natural pig-irons, which used to be more plentifully available than at present, and the characteristics of which were well-defined, regular and known. These artificial irons are rarely, if ever, homogeneous, not only not being regularly well melted, but also being composed of materials which do not readily mix into a homogeneous mass, owing to their widely differing composition and character. It follows that the analyses from different portions rarely agree with one another, and the writer ventures to say they rarely continue to be used in places where there is an experienced chemist.

It is perhaps desirable that those who use such irons and have themselves no chemist, should look with the aid of an experienced consulting chemist, and the help of microscopical investigation also, closely into the carbon conditions that obtain; they would then have a sure guide as to heat effects, as between the natural pig-iron and that which is artificially produced, but orthodox routine laboratory methods as usually practised would not produce results of much practical interest. Apart from this aspect of the question, an investigation of the oxygen contents and other matters occluded in artificially-made pig-iron would without doubt be illuminating.

The writer is driven to the conclusion that it has become again necessary to produce a pig made naturally from iron ores, which will fulfil the conditions demanded by modern foundry practice; which shall be free from oxygen, sound, homogeneous, and of considerable strength. For this reason, he has given some amount of thought to this subject, believing that many varying conditions could be readily met as to grading and different degrees of strength and softness.

It would here be well to say that so far as mechanical tests are concerned, he would rely upon the tensile test only, the transverse test being unmechanical, unreliable and an entirely false guide to the truth. In the first place, there are no straight transverse test bars; in the second place, they are not machined, and therefore are not of accurate measurement; indeed, are not capable of accurate measurement; and in the third place, the characteristics of the iron are in no way properly defined, even if the bar were mechanically accurate. Such irons as the writer speaks of must be judged by the accurately-turned and easily-measured tensile-test bar, which is tested to destruction in an accurate tensile-testing machine. Such tests as those indicated must always accompany any chemical or microscopic investigation so far as any work of research is concerned in castings or pig-iron.

Turning to tests which are not mechanical, the most peculiar matter the writer has ever met with in special strong pig-iron is the demand made by many foundry managers for low sulphur, which is easily understood in a soft iron but which in a strong, tough iron should be comparatively high—many of the old best cold-blast pig-irons contained one-tenth per cent. and over. There is no mistake about it that its effect is to close the grain of the iron, and, up to this amount, it does nothing but good; the idea that it produced unsoundness does not hold good in this class of iron where the tensile strength may be 16 or 18 tons per square inch. Sulphur in iron has so long been regarded as a representative of his Satanic Majesty, upon whom all sorts of sins can be hung, that we sometimes are inclined to forget that circumstances alter cases; even at this day many sins are placed to its credit which are purely imaginary and have no foundation in fact. Nearly all of the so-called sulphide shot examined at Sheepbridge have turned out on investigation by Mr. Houghton to be phosphides, this being, however, in one-and-a-half per cent. phosphorus iron. This point, however, is dealt with by Mr. Primrose, and the writer will not trouble with it any further except to confirm from practical experience what he says upon the subject.

Soundness is, of course, of paramount importance in such an iron where the silicon must be low, as a rule not exceeding 1 per cent. in the very strongest iron of all. Fluidity and soundness were secured in the old irons by five- or six-tenths per cent. of phosphorus and at least seven-tenths per cent. of manganese, often reaching 1 per cent.; the resultant effect of this composition upon the carbon is to produce a very high combined carbon which, indeed, gives it its character for strength as well as, up to a point, fluidity. In this connection, it may be pointed out that the assertion frequently made that the use of cold blast in making such iron has some peculiar effect upon the iron itself is erroneous; the fact is, if the silicon is of the correct percentage in the iron, it does not matter whether the iron is made with cold blast or hot. It is within the experience of all blast-furnacemen at hot-blast furnaces that the blast temperature at times must be lowered to keep down the silicons in the iron, because the furnace itself is too hot or there is a temporary accidental shortness of lime in the slags, and there are few cold-blast furnaces in these days but are

prepared with hot blast to deal with these conditions reversed. It must be, of course, assumed that practically similar materials are used, but the faster driving of hot-blast furnaces and greater knowledge of cause and effect have wonderfully aided silicon control in such a way that such hot-blast furnaces can make just as low silicons as those made in cold-blast furnaces, much of which knowledge has been gained by experience with basic pig-iron of a high-class character.

Two analyses given here, typical of many, are taken from pig-iron used at Sheepbridge, and they illustrate the point:—

	Cold blast. Per cent.	Hot blast. Per cent.
Silicon	1.02	0.75
Sulphur	0.08	0.08
Phosphorus	0.49	0.60
Manganese	0.89	0.78

These irons were made from practically similar materials. The terms hardness and softness have often given the writer much trouble in connection with foundry pig-iron, and being in agreement with Professor Turner's remarks on the subject, he cannot do better than quote them—"Hard cast-iron is brittle, deficient alike in crushing, transverse and tensile strength and seldom gives smooth castings. With metal which is a little less hard the maximum crushing strength is obtained, while on rendering it a little softer, or as the workman would call it, "moderately hard," the maximum transverse strength is observed. With slightly softer cast-iron, the highest tensile tests are obtained. There is a somewhat prevalent idea among founders that if considerable strength is required, a hard iron must be employed. Doubtless this is true in connection with crushing and transverse tests, but certainly not from tensile tests." After all, within the lines of the phosphorus, sulphur and manganese composition suggested, but not necessarily precisely fixed, such iron as the writer speaks of is governed by the amount of silicon it contains and which, in his opinion, as suggested in former Papers, governs, other things being equal, the relative strength or softness required for the purpose for which it is intended. It is manifest that no hematite can in any way enter into the composition of such strong, sound iron as that referred to, and the shibboleth of very low phosphorus, such as that in hematite is, and for years has been, exploded as to its effect in strong cast iron. It can be shown that phosphorus up to three-fourths per cent. does not affect its strength at all, but very materially improves its soundness, and a well-known brand of North Staffordshire cylinder iron easily proves the statement the writer makes.

Supplies of suitable ores for the purposes suggested have for many years been scarce in England, and many of these ores have not been worked at all because they did not appear to be wanted, but there is in the country plenty of the necessary clay-band material referred to for making such natural pig-iron as this Paper suggests should be made to supply the demand, which appears to the author to be increasing with great rapidity. It may be said that such natural iron would perhaps rarely be used exclusively, except for very special purposes, but would be used in admixture with other iron, according to the purpose for which it was required; but it may be taken for granted that it is available in varying degrees of strength and softness as may be desired or demanded.

In the writer's opinion, it is as well to do as little mixing in the cupola as is possible, but rather use a pig-iron directly designed for the castings required; this, of course, is an ideal way of working which in many foundries would be impossible, but for very great strength and soundness in the castings it is undoubtedly the best way. In an air furnace, of course, the matter is different, as this method of melting mixes the iron almost perfectly, being also by far the cleanest method of the two for the iron.

The writer, in investigating this subject, has come across many curious specimens of old pig-iron, which he proposes to deal with in a separate Paper, another time, as they are interesting more as specimens of old practice than as concerning the specific object of this Paper.

(*For discussion on this Paper see page* 511.)

Art as Expressed in Castings.*

By W. F. Bagnall.

One of the features by means of which the Council hope to enlarge this Association's sphere of usefulness is by practical papers and research work. This Paper may fairly be entitled to claim for itself a place in the "research" group; perhaps, not exactly original, but to produce the bulk of the examples shown, art, skill and craftsmanship of the highest degree have been required. The subject is a fascinating one, and the trouble has not been to secure suitable matter sufficient for a paper, but to keep within bounds and not to expand the same into a book.

This particular branch of the trade calls into being a set of workmen (or a more appropriate title would be artists) who are not generally met with in ordinary foundry practice, *i.e.*, designers, modellers, wood carvers, chasers, and men specially trained for filing, etc., the cast-iron patterns, made in many instances from the master patterns. Many illustrations in connection with this branch of the foundryman's art will be found, usage of what has been described as the "Lost Wax Process." I make no apology for using the term art in connection with a moulder or foundryman; there has yet been no moulding machine invented possessing brains, and these are required in a very high degree to produce most of my examples, very few of which would be suitable for reproducing on the machine, either "turn-over draw," "roll-over," "jarring-ram," "stripping-plate," "squeezer," "gravity," or other types. The writer believes, however, that, as a rule, the wax process is simply employed to get the first impression in lead or composition for the master pattern, which is chased and only used to produce a cast-iron pattern from, and kept afterwards in case the iron one breaks, or wears out, or a new pattern is required with some slight alteration.

Great strength and chemical composition are not important factors in the iron employed in the manufacture of most of the castings here described, but to successfully cast the majority a very fluid iron is required, possessing a fairly high silicon content, which must fill all the corners of the mould, leaving a casting true to pattern, with a perfectly sharp and clear impression of all the ornamental details of same.

* Abstract.

Examples of Art as Expressed in Castings.

FIG. 1.—REGISTER STOVE. FIG. 1A.—DOGS FOR STOVE SHOWN IN FIG. 1. FIG. 2.—DOG GRATE, BY STEPHENS. FIG. 3.—REGISTER STOVE AND FENDER COMBINED. FIG. 4.—HALL STOVE. FIGS. 5 AND 6.—PANELS, BY W. & H. HAWARTH. FIG. 7.—UMBRELLA STAND IN CAST IRON.

One of the most suitable classes of pig-iron for this purpose comprises the various brands of the famous Scotch pig-iron produced near Glasgow. The moulding sand used is a very important factor. The district from which the writer comes is very well situated in this respect, being quite close to the famous sand quarries of Worksop and Mansfield. Birmingham is also particularly favoured in this respect with its noted cemetery sand, which is largely employed in Sheffield for fine, false-cored work to be cast in silver, etc.

This Paper does not purpose giving a history of cast iron, but the author would like to touch upon one or two points as illustrating the growth of the manufacture, compared with the growth of art and design in castings. About the year 1709 a number of enterprising manufacturers tried to make iron by a system of using pit coal. Their efforts were crowned with success, chiefly owing to the Darbys, who, with the aid of skilled Dutch workmen, began the celebrated Coalbrookdale Works. In a journal issued in 1846, we find Coalbrookdale Iron Works mentioned as being in existence since the time of Charles I., but it was not until 1707 that Mr. Darby, of Bristol, took over the works.

Ornamental castings were first successfully made about the year 1834, before which time such work was considered impossible. It is rather a difficult matter to classify all the examples selected for exhibition, but the two classes that would include most of the specimens would be internal and external decoration. From an art point of view, internal decoration supplies us with the largest number of examples, and some of the most famous and noted names in the world of art. These, however, chiefly occur in the 18th and 19th centuries.

Naturally, stove grates make the largest item of internal decoration on which the skill of the artist and ornamentation in cast-iron can be most displayed to advantage. The history of the fireplace falls into two main divisions, that is to say, according to the fuel burnt—the "wood" period and the "coal" period. At first there was the hearth in the middle of the room, and later the introduction of the brazier. Then the fireplace was removed to the wall, hooded or recessed, according as British or French custom or practice prevailed. The use of sea coal was introduced during the reign of Charles I., and Inigo Jones was designing at the time a few very fine fireplaces. The adoption of the new fuel by the less well-to-do heralded the coming of the firegrate.

To go back to remote antiquity—the days when our ancestors first discovered the art of obtaining fire—probably a few large stones kept together the brushwood burned, necessity, the mother of invention, providing the idea of confining the fire within defined bounds. Following these lines, the basin of metal or the brazier, which was suggested by natural devices, was the first form of metallic grate used. It was used by the Egyptians, Greeks, and Romans as a receptacle for charcoal, and "fire devils" of identical shape may be seen with us still whenever our streets are undergoing repairs. The writer will leave the history of fireplaces at this point, as all the earliest examples are made of wrought iron, enriched, in some cases, with ornamentation of copper, and, of course, do not come within the scope of cast iron, and pass on at once to the 18th century, which gives us the first examples in cast iron.

Fig. 1 is a register stove, with fender and ashes pan, etc., combined, a very neat but not ornate design. The two figures shown in Fig. 1a belong to and are shown with the stove, but are enlarged for the purpose of showing the design and detail more prominently.

Fig. 2 is a sample of Stevens' work as applied to a dog grate. The chief feature of the ornamentation work in this illustration lies in the back and dogs or fire rests. The dogs are a beautiful exemplification of craftsmanship, both from the point of design and as an example of the moulder's art, and are executed in bronze.

Fig. 3 is a Stevens' design for a register stove and fender, etc., combined; old fashioned maybe, and, pernaps, not very economical in the use of fuel according to present-day ideas, but chaste and elegant in design. Look at the fine ornamentation on the metal back, which would be obscured by smoke and soot every time the fire was lit; from an art point of view, however, the work is one of genius.

Fig. 4 is a handsome specimen of a hall stove, worthy to grace the entrance hall of any mansion, and is surely the high water-mark of art possible in this direction. It is a very finely executed work, full of detail, but not too highly decorated to take away from the completeness and elegance of the design as a whole.

The panels in Figs. 5 and 6 are by the celebrated artists William and Henry Hawarth, who were pupils of the Royal Academy during the presidency of Sir Joshua Reynolds. These designs are the property of the Carron Company, and were executed in the 18th century. The carvings are masterpieces of the carver's art, and the great variety of fireplaces made from them to-day attests the skill of the designers and workmen alike, combining as they do that grace and perfect finish which are the aim of every true artist and intelligent craftsman. The beautiful execution and detail of two examples arrest attention, viz., "The Shrine" and "Venus and Adonis," which are masterpieces both in design and execution. The Company are fortunate in possessing many other specimens of these artists' work, which worthily uphold their world-wide reputation for artistic castings.

Fig. 7 illustrates an umbrella stand in the writer's house, made of cast iron. The modelling of the boy is a fine specimen of art, and attributed to the late Godfrey Sykes, but this cannot be vouched. The patterns were bought at a sale of a local foundry now non-existent. The stand is painted in natural colours, and so life-like that strangers are quite startled on first seeing it.

Fig. 8 is an illustration of cast iron as applied to furniture. The example shown is by a Rotherham firm now out of existence, and acts as a hat and umbrella stand, with hall table combined, and altogether is a very creditable piece of workmanship. The table top is of marble, and the mirrors are fine plate glass. The design is typical of the period—the early Victorian—and combines modelling of the beautiful and grotesque, enriched with floral and conventional ornament. Notice the children's figures supporting plates of fruit and the birds approaching same; the mask or man's face over the centre mirror and the two animals' heads on the side panels, which terminate in a beautiful leaf and fruit design. It is a large size, and requires a spacious entrance hall to show it to advantage. The height is 8 ft. 10 in., the extreme width 7 ft., and the depth about 1 ft. 8 in.

External Decoration.

Naturally with this section, perhaps, the writer is not able to give so many specimens of what may be described as productions of the very first rank in high-class art. Of course, this, to a great extent, may be accounted for by the fact that cast iron and even bronze suffers considerable depreciation from exposure to the atmosphere, especially in our large cities and towns. For the inventor who can produce a cast-iron or a bronze impervious to atmospheric effects, a large fortune awaits. Some of the most beautiful examples in this section are of cast-iron entrance gates, and the writer has been successful in securing one or two particularly fine specimens.

Examples of Art as Expressed in Castings.

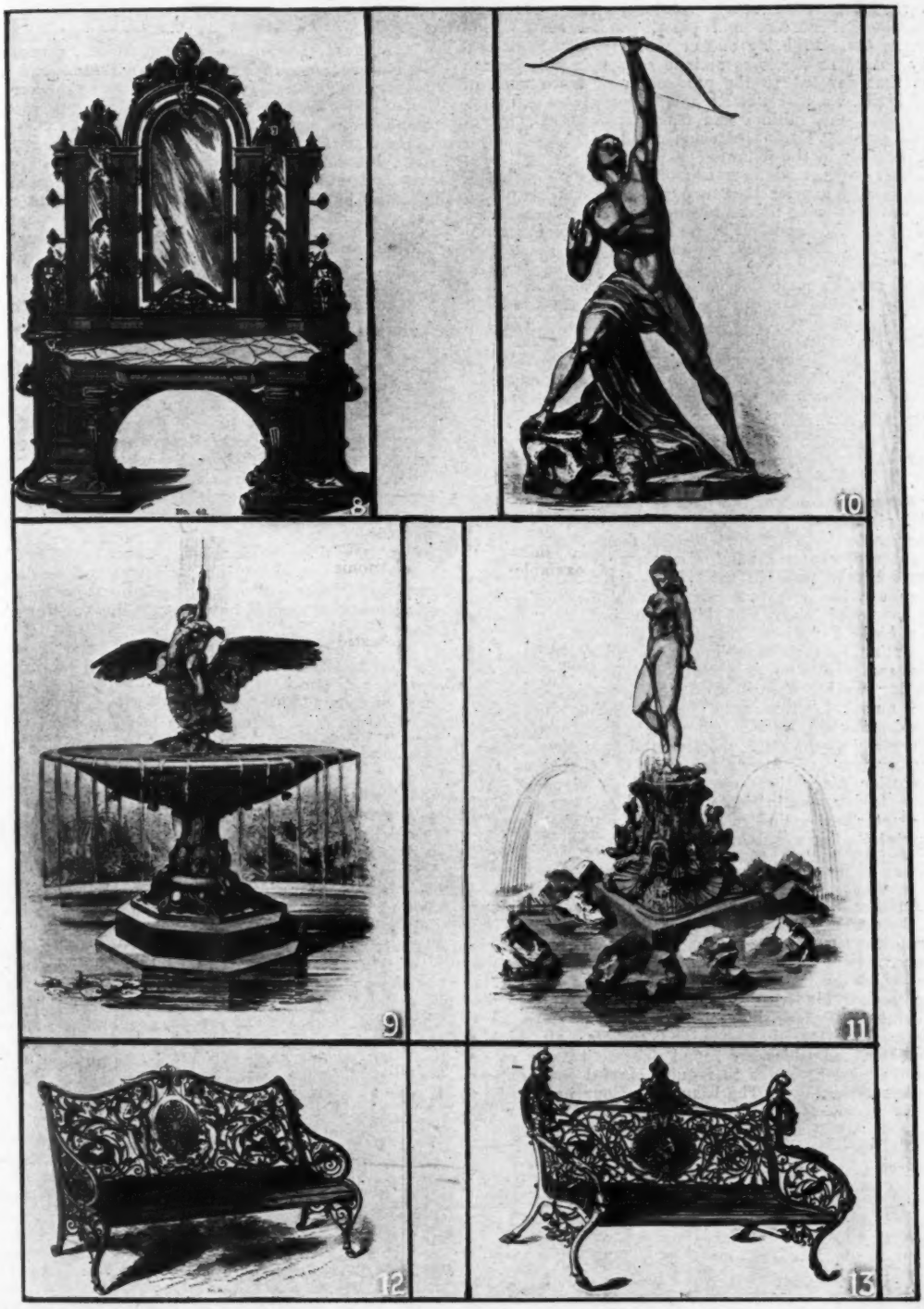


FIG. 8.—HAT AND UMBRELLA STAND IN CAST IRON. FIGS. 9 AND 11.—FOUNTAINS IN CAST IRON, DESIGNED BY JOHN BELL. FIG. 10.—"THE EAGLE SLAYER," BY JOHN BELL, CAST IN IRON. FIGS. 12 AND 13.—GARDEN SEATS IN CAST IRON, BY THE COALBROOKDALE COMPANY.

Other items in this class are fountains both for gardens and public monuments, balconies and verandahs, ornamental columns, tomb railings, ornamental gutters and pipes, garden seats, lamp posts, etc. Probably one of the most important and by no means the least artistic section in this branch is that devoted to the production of fence work of all kinds, viz.:—Entrance gates, hand gates and piers for the same, railings and fencings, crestings, friezes and panels. Gates are constructed in various ways, principally in the following:—

Cast gates, made in panels or sheets, which are proportionally heavier than wrought ones, the nature of the designs being therefore wholly different from either of the other kinds. For large gates they are more massive in appearance, whilst for smaller gates they are less costly than wrought iron. Wrought gates with cast or malleable enrichments combine the best characteristics of both materials, viz., the strength and lightness of wrought-iron framing and the full effect of cast-iron work in the panels or enrichments. In the smaller applied parts these castings are in malleable iron, and in some of the designs undercut work is introduced with excellent effect. Of course, wrought-iron gates pure and simple do not enter within the scope of this Paper.

French Castings.

France was one of the pioneer countries to produce high-class artistic castings, in many respects not acceptable to English taste as regards their very florid ornamentation and also their very free treatment of the nude in art. With their workmanship they can challenge comparison with the world, and in beauty of design and skill in casting, they deserve the highest praise. They pay a great amount of attention to their moulding sand and preparation of the same, a very important detail in ornamental casting work. French sand and loam is largely in use amongst silversmiths for producing fine false-cored figure work, etc. In the casting of figure and statue work, monumental and other crosses, cups, vases and fountains, etc., their designs and execution place them on a very high plane of art. Even to-day, the intricate and thin castings required for motor-car cylinders which they make have a reputation the world over.

Berlin Work.

Another section covers the famous specimens of the moulder's craft known as Berlin castings. The exquisite character of the Berlin iron castings is known and acknowledged on all sides, and also the perfection to which those works may be carried in the smaller kinds. Even jewellery used for personal decoration is made in cast iron. Finger rings, earrings, brooches, bracelets and caskets, all highly decorative, in which are found delicate tracery of so minute a character as to require careful examination to detect the lines. The beautiful colour imparted to the work enhances its value, by its tone and unpretending character.

Castings for Gardens.

The next section to be illustrated consists of articles for use in gardens, lawns, etc., and comprises examples of garden seats, vases, flower pot stands, fountains, etc., many of which are specially adaptable for high-class artistic adornment and design.

The fountain shown in Fig. 9 is the production of the Coalbrookdale Company, and is English workmanship and design throughout. This was designed and modelled by the late John Bell, R.A., the sculptor who produced the group of "America" for one of the corners of the Albert Memorial in London. The "Boy and Swan" is an example by Bell at his best, and the workmanship, from the moulder's point of view, of the very front rank.

Fig. 11 is another example of the work of John Bell, depicting Andromeda chained. The graceful figure of Andromeda from the sculpture has been excellently rendered, and is a work in every way honourable to British art manufacture. As an example of casting it may take rank with the very best specimens exhibited. The figure is very elegantly conceived, and has a charming simplicity of treatment, and is worthy to rank with the very best French art in this class. The pedestal is a work of much fancy, and is in the highly-wrought style of the Cellini period. It is emblematical throughout of the story of the figure it supports.

Fig. 10 is John Bell's famous statue of "The Eagle Slayer," cast in either iron or bronze, of noble proportions, standing about 8 ft. high. A criticism of this work of art would be an impertinence. The photo speaks for itself of its merits.

The two examples shown in Figs. 12 and 13 are by the Coalbrookdale Company. The first is a very elegant design, well executed, and a suitable adornment for any garden. The other, however, is the one to which special attention is drawn. This is a fanciful and beautifully executed design, but the centre panel cannot be commended, the female figure in which seems a complete caricature. Probably this would not appear so in the actual casting, and may be due to the print from which this picture is taken, an old wood cut of 1878. On examining the specimen in detail, an extremely good effect is secured by the depicting of a silken rope, which is draped along the back, twines through the centre and side posts and through the mouths of the fabulous animals' heads, and ends in tassels resting on the arm of the seats. The arms are ornamented with masks, and the legs terminate in representations of hoofs. A feature of the design are the fine bird models in the pattern, those on the arm appear very natural and life-like. The flower and leaf sprays on the legs underneath the seat are well worked out. A fine example of light ornamental castings applied to everyday use; a credit to designer and manufacturer, and a thing of beauty to place in any garden.

Queries.

Trouble with Pump Castings.

We are making pump castings which have to stand a very high pressure, and are experiencing great difficulty in getting them solid right through; after being machined and when they come to be tested they leak. Also we make the blank wheels for the above (from 3 ft. up to 6 ft. in diameter, arms ⅝ to ¾ thick, 9 in. bosses in centre by 5 in. deep, and the rim 8 in. deep by 3 in. thick). The teeth are all cut, but we have a difficulty in getting them solid—they show spongy at the bottom of the teeth when cut, which condemns the otherwise good casting. We use the best of Scotch and Lincoln pig-iron, half-and-half, with half of good machinery scrap. The down gate for the wheels is about 2 in. diameter to the centre boss, and fed there. Can any of your readers give an idea of cause and possible remedy? "W. R. R. M."

Answer.—The grade of Scotch iron used by our correspondent is not stated, but in our opinion neither Scotch nor Lincoln pig with scrap is absolutely suitable for the castings mentioned. The difficulty experienced in getting the castings thoroughly solid is very prevalent, especially so where only ordinary graded irons are employed, and we consider some such irons as "Frodair" and "Lydka Cylinder" should be utilised, in the proportion of, say, 25 per cent. (or a little more if possible) of each, and the remainder good-quality scrap. With this mixture, a really sound and solid casting should be obtained, provided the iron is run very hot and cast energetically. A heavy head is also very essential.

Mixture for Baths.

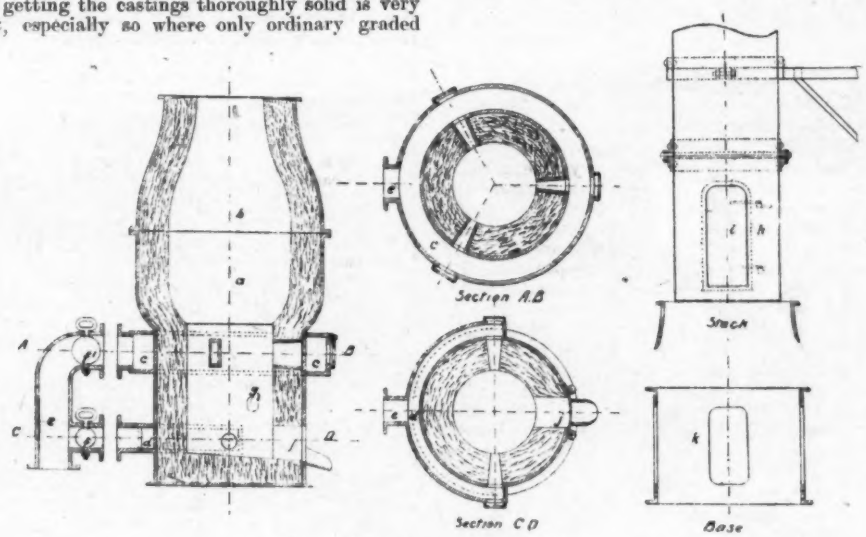
Can you give me a mixture of metal for baths. I have trouble with them cracking. They are put into a muffle for the purpose of enamel, and many crack when taken from the muffle. "C. P. R."

Answer.—Our correspondent gives no indication as to his present mixture, consequently we are not in a position to say anything as to its suitability, or if it allows some adjustment to yield better results. We might, however, refer him to The Frodair Iron and Steel Company, Limited, of Fenchurch Street, London, as they have an iron—"Norrfield L.M.," which is suitable for such castings.

Small Cupola Furnace for Cast Iron.

The small cupola shown in the drawing is very useful for ironfounders who only make castings occasionally, and is particularly adapted for special castings. It is built up of two parts, the cupola *a* and the neck *b*, and is provided with an air chamber *c*, supplying blast to the upper tuyeres for the melting process, whilst a second air chamber *d*, enables air to be introduced just above the hearth of the furnace for heating it up. These chambers are connected by a pipe *e*, provided with valves *f*, *f*¹, through which the air is fed to one or other of the chambers.

The lower tuyeres enable the furnace to be heated up in 15 minutes, and the first melt to be utilised. The tap hole is made at the beginning of heating up, and a slag hole *g*, is provided for running off the slag. The stack is supported independently, so that the neck of the furnace can be removed for repairs.



Small Cupola for Cast-Iron.

The lower part *h*, of the stack can be detached in order to leave sufficient space to get at the interior of the cupola for cleaning or repairs. The charge is introduced through a door *i* arranged in this lower portion of the stack.

The furnace will melt 12 to 14 cwt. per hour. The crucible holds 3—3½ cwt., and the top about 5 cwt. It can be started with 66 lbs. of coke. Six cwt. of metal can be melted and poured in an hour, including the time occupied in heating up; and castings (pillars, etc.), up to 3—3½ cwt. can be obtained in good condition.

The furnace is lined with fireclay 4½ in. thick, which will last out the working of 12 to 15 charges of 16—20 cwt. of metal without needing repair. This applies to the fusion zone, the upper portions having a working life two or three times as long. The tap hole *j*, 4 in. by 5½ in., is arranged just above the lip, and the sand plug closing this hole is kept in position by an iron plate. The cupola is mounted on a cast-iron base *k*, about 18 in. in height.—"La Fonderie Moderne."

Foundry Plant and Equipment.

The "Perkins" Pattern-Maker's Bench.

The pattern-maker's bench shown in the accompanying illustration has a specially prepared hardwood top and is securely bolted on to two iron legs, which in turn carry two shelves, secured by four tie bars. As will be seen, this type of bench allows full use of the shelves without their becoming the receptacle for shop refuse, as usually happens with the old-fashioned well. The hardwood top is, in length and breadth, slotted with holes to accommodate an adjustable steel top for cramping purposes. Each iron standard is provided with a special carrier, which enables one man to hold and shoot the edges of long, heavy boards without the help of a labourer or packings. When required for large work, the bench is fitted with an automatic tool rack which enables a man to have a clear, flat top at once, without moving a tool from its regular place. At the front end two adjustable wood planing strips are provided.

THE "PERKINS" PATTERN-MAKER'S BENCH.

The "Perkins" vise has been specially designed for use in up-to-date pattern shops and is the outcome of long experience in the difficulties pattern-makers are faced with every minute, viz., to securely hold straight and irregular shaped work, without danger of slips or marking. The vise is operated by a continuous quick screw and is entirely without complicated parts, and is fitted with automatic adjusting attachments, by which taper, circular, oval and segmenal work, etc., may be securely held; in fact any regular or irregular form. In addition it is provided with a vertically adjustable steel stop which enables work too large for the jaw opening of the vise to be clamped either across or along the top of the bench. The fullest advantage of this vise is obtained when used in conjunction with a "Perkins" bench. The makers of the foregoing apparatus are Messrs. Chas. Hall & Co., Newton Ironworks, Dixon Street, Dantzic Street, Manchester.

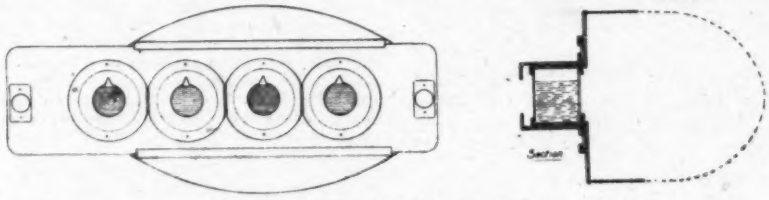
The "Stereo" Pyrometer.

An interesting and useful form of pyrometer is illustrated in the accompanying drawing. It is applicable for ascertaining the temperatures of muffles, crucible furnaces, gas retorts, kilns, malleable-iron furnaces, open-hearth, case-hardening, annealing and other furnaces. It is used like a stereoscope—hence its name, "Stereo" pyrometer. The apparatus consists essentially of small glass cells containing dyes, the absorptive powers of which are so chosen that all the light of whatever colour emitted by a hot body is absorbed.

As the intensity of the light and the range of wave lengths emitted by any one body is a function of its temperature, it follows that cells can be constructed, each corresponding to a definite temperature. A great number of dyes of all concentrations have been examined spectroscopically to test their specific absorption. In combining these, it was discovered that the eye was more sensitive for the change from darkness to a certain wave length in the dark red, than from darkness to a combination of all the wave lengths emitted. When the luminosity of a coloured object is very much reduced, a point arrives at which it no longer appears coloured, although still visible, but presents usually a pale, greyish phosphorescent colour. This is supposed to be due to the fact that the rods of the retina are not sensitive to colour, though giving the impression of light, the colour appearing as soon as the intensity is sufficient to stimulate the cones of the retina; the change from a phosphorescent glow to the almost complementary dark red (which is allowed to predominate in the dye mixtures) is very sharp.

The stereoscopic form enables both eyes to be used, while no accessory instrument is required as in the case of electrical pyrometers and the radiation pyrometer. The "Stereo" pyrometer is a zero and not a comparison instrument; the point observed is when the object just disappears from view. No standard tints or constant illuminants are required as in the

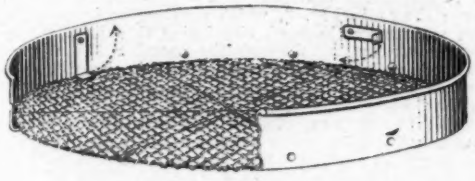
case of the absorption or optical pyrometer. The instrument is used at a distance away from the hot body, so that no part of it suffers from the chemical changes, disintegration and depreciation which all bodies experience at high temperature. It can be used at any convenient distance so long as the intervening space is comparatively free from smoke, etc. It should be noted, however, that it cannot be used unless the hot body is visible either directly or by reflection. It gives readings that are slightly too low if thick layers of carbon monoxide, carbon-dioxide or water vapour are interposed. If dense fumes are interposed, the readings will be distinctly low. The temperature of an object in a furnace appears slightly higher than the same object out of the furnace.



THE "STEREO" PYROMETER.

In using it to ascertain the temperature of article in, say, a case-hardening muffle, it is not necessary nor desirable to raise the door or front of the furnace, for the articles can be viewed through an observation port located at any convenient part of the furnace. The pyrometer is applied to the eyes, and in half a minute the articles will be visible as a deep maroon or crimson patch of the same shape as the observation port, if their temperature is higher than that engraved on the cell caps.

When it is desired to maintain one steady temperature the employment of the form illustrated is recommended. This contains two pairs of cells, one for a temperature slightly higher than the other. The articles or furnace will be at the correct temperature when the observation port is visible through the lower and invisible through the higher cell. The makers of the apparatus are Messrs. W. and J. George, Limited, Great Charles Street, Birmingham.



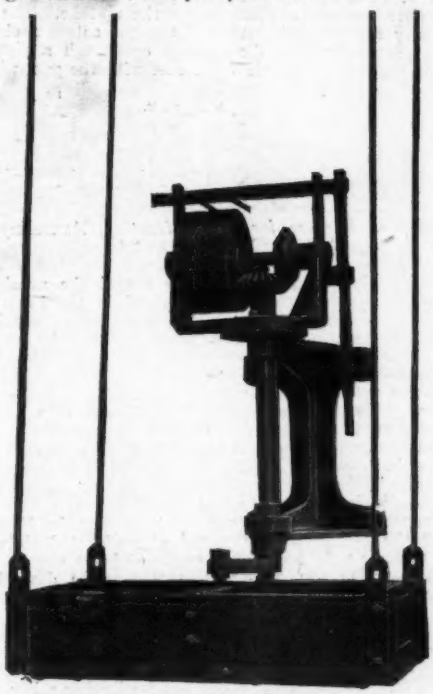
WYLLIE'S FOUNDRY RIDDLES.

Wyllie's Riddles.

The hand riddle shown herewith is made by Messrs. W. L. Dobbie & Co., 68, Gordon St., Glasgow, who claim that its construction enables considerable economy to be effected. The rim, which is galvanised after being made, is said to be practically indestructible, and neither warps, twists nor rusts. It is stamped out of one piece of steel without weld or joint and serves for any size of mesh. New bottoms can be easily fitted, without tools, and be held securely in positions. When the bottom is worn out the rim is still intact and serves for at least 30 further bottoms, and this method of replacing is said to save 33 per cent. of the cost of ordinary new riddles. The size of the rim is 21½ inches diameter and the bottoms are of 1-16 inch mesh upwards.

Swinging Sand-Sifter.

Another useful foundry appliance, made by Messrs. Chas. Hall & Co., is the swinging sand-sifter shown herewith. This machine has been designed to meet the wants of an efficient sand riddler at a moderate cost. The framing is of cast-iron, well stayed. The upright shaft and loose pulley are fitted with self-oiling bearings. The riddle is suspended by four rods, and motion for same is taken from the crank, fastened to the vertical shaft, which is driven by the gearing and pulleys, etc. The fast and loose pulleys can be set to any angle, as the framing of same is adjustable. The inside dimensions of the riddle are 19 in. × 36 in., and the depth is 9 in.



SWINGING SAND-SIFTER.

D

Inventions.

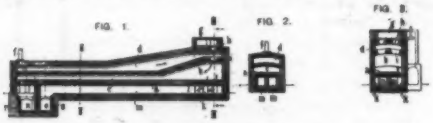
Applications for Patents.

An asterisk indicates that a complete specification accompanies the application. When inventions are communicated the names of the communicators are in brackets.

16,696.*Production of cores or moulds for metal-casting purposes. W. Kurze.
16,734.*Manufacture of cores and moulds for casting purposes. W. Kurze.
16,827. Casting ingots, etc., of steel or other metals or alloys. H. C. Law.
17,021. Castings. W. H. Millspaugh.
18,406. Refining molten pig-iron for steel-making. T. Twyman.
18,414.*Cupola furnaces. P. Anderson.

Abstracts of British Patent Specifications recently accepted.

12,747 (1910). *Process of, and Gas-fired Furnace for use in, the Heating, Annealing, and Hardening of Metals.*—Paul Schmidt & Desgraz Technisches Bureau, G.m.b.H., Hanover, Germany.—Fig. 1 is a vertical longitudinal section of the furnace, and Figs. 2 and 3 show vertical cross sections on the lines II—II and III—III respectively. Above one end of the hearth *a* is provided the combustion chamber *b* for the gas and air mixture. The combustion gases pass from here through the upper combustion passage *c* to the up-take. The air necessary for the combustion of the gas enters a chamber *d* provided above the passage *c* through a pipe *f*, and in front of the nozzle *i* it mixes with the gas, which

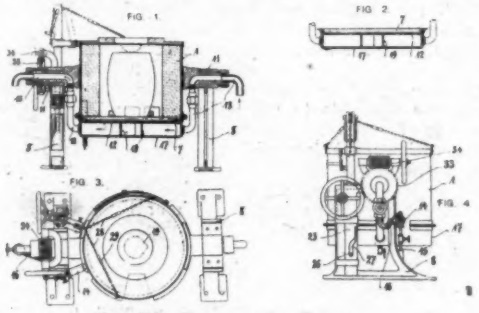


Gas-fired Furnace for use in Heating, Annealing, and Hardening of Metals.

is conducted through the passage *g* and the nozzle *h*. Below the nozzle *i* there are provided in the hearth *a* apertures *k* which lead into the passages *m* provided below the hearth *a*, so that the latter can be heated from both sides. The gases from the upper passage *c* are conducted by the up-take *n*, which is controlled by a damper *r*, to the flue; whilst those from the passages *m* are conducted to the flue by the up-take *o*, which is provided with a damper *s*. It is therefore possible, by the adjustment of the dampers *r* and *s*, to conduct the combustion gases either only through the upper passage *c* or through the lower passages *m*, or the gas current can be divided, so as to pass simultaneously through the upper and lower passages. As shown in Figs. 2 and 3 the hearth is constructed of perforated slabs in such manner that continuous series of holes are formed through which the articles that it may be desired to anneal, are passed.

14,955 (1910). *Manufacture of Steel for Armour Plates, Guns, and other Steel Articles.* W. Beardmore, Parkhead Forge Rolling Mills and Steel Works, Glasgow.—According to this invention the steel, besides having a low percentage of carbon, contains metallic constituents other than ferrite, which constituents are of such a character and are used in such proportions that the strength and toughness of the steel are afforded by the solution of the constituents in the ferrite. The proportion of carbon in the steel is so low that the hardening carbon formed on heating the steel above the first critical point Ac, (but not above the second critical point Ac_3) has little effect upon the toughness. The carbon should not exceed 0.25 per cent. The most important of the metallic constituents employed are molybdenum, nickel, and tungsten. These three metals are always present. The composition of a steel found satisfactory is as follows:—Carbon, 0.15 to 0.25 per cent.; molybdenum, 1.00 to 2.00 per cent.; nickel, 5.00 to 6.00 per cent.; tungsten, 0.25 to 1.00 per cent.; manganese not exceeding 0.50 per cent. ferrite, the remainder. In addition to the above-stated constituents, the steel would contain some small percentage of sulphur and phosphorus, which, however, should of course be as small as possible..

17,238 (1910). *Crucible Furnaces.* W. Buess, 41, Stader, Chaussee, Hanover, Germany.—Fig. 1 is a vertical section through a furnace; Fig. 2 is a similar view of the detachable base; Fig. 3 is a plan; and Fig. 4 is a side elevation. The furnace comprises a shaft 1, provided with hollow trunnions 2 supported in bearings 11 formed in supporting standards 8, so that the furnace can be tipped. The casing has a bottom comprising a slab of refractory material 7 supported by a metal plate 12, which is provided with flanged edges so that the plate and the refractory material which it supports can be bolted to a corresponding flange on the bottom of the casing. Formed on the under side of the plate 12 is a hollow chamber 17, through which cooling air is circulated, supplied by a pipe 18 which passes through the hollow trunnions 2 in the usual manner. The chamber

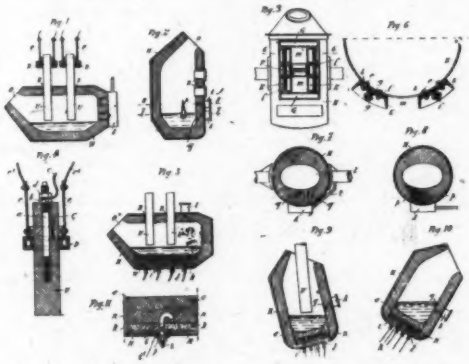


Crucible Furnace, by Buess.

17 is preferably provided with a baffle plate 19 of the shape shown in Fig. 3, which divides the incoming air and ensures its thorough circulation through the chamber. After passing through the chamber 17 and being warmed, owing to the proximity of this chamber to the hottest part of the furnace, the cooling air is supplied to the fuel nozzle 14 through a pipe 16 shown in Fig. 4. The liquid fuel is supplied to the nozzle through a valve-controlled pipe 15, and a valve is also supplied to control the supply of compressed air to the nozzle. It will thus be seen that the compressed air which injects the liquid fuel, not only serves to cool the hottest portion of the furnace, which is most likely to be worn out, but is simultaneously warmed prior to its mixture with the liquid fuel to form a gaseous mixture employed to heat the crucible. To effect the tipping of the furnace when the crucible is to be emptied a worm wheel 33 is employed, this wheel being keyed to one of the trunnions 2 and engaged by a worm 34 rotated by a hand wheel.

18,010 (1910). *Manufacture of Hard Steels Direct from Cast Iron.* H. A. G. Cinille, Epierre, Savoy.—Fig. 1 is a converter in section arranged for the blast to be applied through the bottom or end, the converter being shown in the horizontal position for the passage of the electric current. Fig. 2 is a section of the converter arranged for the blast to be admitted through the side, the converter being shown in its vertical position for the blowing operation. Fig. 3 is a section of a converter of which a part of the lining itself serves as an electrode. Fig. 4 is a section on a larger scale showing an electrode and the method of making the electric connections. Fig. 5 is a rear elevation of the converter. Fig. 6 is a section on a larger scale taken on line 6—6 of Fig. 5. Fig. 7 is a cross section with lateral blast, the section being taken on line 7—7, Fig.

2. Fig. 8 is a cross section on line 8—8, Fig. 2. Fig. 9 is a vertical section of a converter with lateral blast and having a single electrode and a tuyere inclined towards the bottom of the converter. Fig. 10 is a view similar to Fig. 9, and showing the converter put into position for the blowing operation. Fig. 11 is a detail view on a larger scale showing the lining of the converter arranged to serve as an electrode. In the arrangements shown in Fig. 1, 2 and 3, the converter should be put into the horizontal position for the application of the electric current, whether the electrodes U are of opposite polarities, as in Fig. 1 or whether the two electrodes U are of the same polarity, as in Fig. 3, the current then passing through the molten metal and the part of the lining of the converter forming the other electrode of opposite polarity to that of the electrodes U. The electrodes U are at the back of the apparatus on the side where the nozzle O is located. In the converters with lateral blast (Figs. 2 and 3), the openings B serving for the passage of the carbons



Manufacture of Hard Steels direct from Cast-iron.

U are above the blast box A. The electrodes U U are suspended from supports, independent of the converter, which are provided with winches, and ropes for manipulating the electrodes and also serve for supporting the terminals for the current. The electrodes are lowered into the furnace through the openings B when the converter is horizontal. Each electrode may be formed (Fig. 4) of a carbon electrode proper, U, lengthened by a head C of carbon, or metal, into the electrode U and through the head C passes a copper rod *a* tapped at its lower end to screw into the top of U and having its upper end threaded to receive a clamping nut *b*; this rod *a* is utilised for admitting the current by means of a conductor *c* clamped by a jamb nut *d*. The current also passes to the electrode through a cast iron collar D, which is made hollow to allow of a circulation of cooling water; this collar has copper cheeks *e* to which are fixed conductors c^1, c^2. The current therefore passes to the head of the electrode by the enclosing collar D and by the rod *a*.

29,830 (1910). *Manufacture of Iron and Steel.* A. Boucher, Prilly, Canton Vaud, Switzerland.—This invention relates to an improved process of obtaining alloys of iron and steel by the use of electrolytically deposited iron, by means of which it is possible either in an electric, Bessemer or Martin furnace, or a melting or crucible furnace to obtain iron and steel of an exactly predetermined quality and without impurities. This process consists in using as raw material for supplying the furnaces in question, iron obtained by electrolytic refining of cast iron, for instance, by the Boucher process forming the subject of Specification No. 28,746 of 1910, other metals in the pure form which it is desired to alloy with the iron being added in the desired proportion. In using this iron, which may be considered as practically pure, it is possible to obtain during the operation, exact proportions, both of carbon and of other metals and metalloids, to be incorporated into the iron for the purpose of obtaining iron and steel of a strictly predetermined quality and without impurities, whether it be question of ordinary steel or of special iron or steel, such as tungsten-steel, nickel-steel, chrome-steel, ferro-nickel, ferro-chrome, etc. The operation is simplified in the sense that, by adding to the chemically pure iron substances which are also chemically pure, such as carbon, tungsten, etc., the operation is reduced to a simple mixing by melting or fusion.

Trade Talk.

RICHARD PAPE, LIMITED, have removed to Belvedere Works, Belvedere, Kent.

MESSRS. J. PARKINSON & SON are extending their Canal Ironworks, Shipley.

THE CARRON COMPANY are extending their foundry at a cost exceeding £6,000

MR. F. L. RAWSON, consulting engineer, has removed his offices to 3, London Wall Buildings, E.C.

EXTENSIONS are being made at the works of Messrs. G. Cradock & Company, Limited, Wakefield.

MESSRS. FREDERICK RYMAN & COMPANY, engineers, have removed to 116, Livery Street, Birmingham.

MESSRS. ROBERT HUTTON & SONS, ironfounders, 5, George Street, Whitby, Yorks, are relinquishing their business.

A NEW machine shop is to be erected at the Wharf Foundry, Well Street, Bolton, Lancs., owned by Messrs. Jackson & Brother.

MESSRS. CHRISTY & NORRIS are making extensive alterations and additions to their Broomfield Road Iron Works, Chelmsford.

L. GARDNER & SONS, LIMITED, are adding laboratories and other extensions to their Barton Hall Engine Works, Patricroft, Manchester.

AT an extraordinary general meeting of Messrs. James H. Tozer & Son, Limited, it was resolved to voluntarily wind up the company.

F. PRATT & COMPANY, LIMITED, of the Eagle Iron Works, Victoria Street E., Halifax, have been placed on the Admiralty list.

CALDWELL & COMPANY, LIMITED, have appointed F. S. Dudgeon, Limited, 30, Great St. Helens, London, E.C., as their London agents.

THE new works of Messrs. Andre Citroen & Company situated at 31, Quai de Grenelle, Paris, were officially inaugurated on July 22 last.

MESSRS. JOSEPH RHODES & SONS, LIMITED, engineers and ironfounders, are making extensions to their Grove Ironworks, Kirkgate, Wakefield.

JAMES CLEWS & SONS, LIMITED, brassfounders, 195, Aston Road, Birmingham, have established branch works in Dartmouth Street, Birmingham.

MESSRS. F. EVANS & G. MARTIN, carrying on business as engineers at 20, Portia Street, Liverpool, as Evans & Martin, have dissolved partnership.

MESSRS. BROWN, BROWN & COMPANY, engineers and machinery merchants of Victoria Mills, Low Pavement, Chesterfield, are relinquishing business.

MR. H. W. TEETON, engineer, has moved temporarily to 19a, Lichfield Street, Hanley, as his old premises at Foundry Works were destroyed by fire recently.

THE engineering works of Messrs. E. R. & F. Turner, Limited, at Ipswich, which cover over four acres, were almost completely destroyed by fire on August 21.

THE works of the Brett's Stamping Company, Limited, Coventry, are being extended, as also are the premises and plant of the Sterling Metals, Limited, Coventry.

MESSRS. PARKER & HEAGERTY, 48, Lime Street, E.C., have been appointed London export agents for Sperryn & Company, Limited, brassfounders, of Birmingham.

MESSRS. BARKER, SPINK & LEASE, engineers, have removed their business from the Springfield Works, Guiseley, Yorks, to the Park Works, Rosse Street, Shipley.

JONES & ATTWOOD, LIMITED, Titan Works, Stourbridge, have acquired the hydraulic engineering business of Birch, Killon & Company, Cooper Street, Manchester.

THE FALCON IRON WORKS, LIMITED, of the Falcon Iron Works, Oldham, have appointed Messrs. H. Mackay & Company, 4, Southampton Row, W.C., as their sole agents in London and district.

HAM, BAKER & COMPANY, LIMITED, engineers and ironfounders, of 13, Grosvenor Road, Westminster, London, S.W., and the Municipal Engineering Works, Langley, Birmingham, are extending their works.

THE London offices of the Carbrook Steel Works, Limited, Tinsley, Sheffield, have been removed to 11 & 12, Clement's Lane, E.C. Messrs. Campbell, Macmaster & Company are the company's sole London agents.

THE firm of James Morrison & Company, Sea View Iron Works, Bo'ness, has been dissolved. Mr. A. W. R. Durham, 33, Charlotte Square, Edinburgh, has been appointed trustee for the purposes of the winding-up.

MR. A. L. CURTIS, consulting engineer, late of Johannesburg, Philadelphia, and Chatteris, has associated himself with the Frodair Iron & Steel Company, Limited, and is representing them in Manchester and district.

MESSRS. R. LEADLEY, R. HUNT, A. WATTS, and R. A. PALMER, carrying on business as brass founders, at 82, New John Street West, Birmingham, under the style of Robert Leadley & Company, have dissolved partnership.

AT the Leeds Court on July 19, Mr. J. P. Burgess, 38, Albion Street, Leeds, was appointed liquidator of the Bosshardt Casting Process, Limited, of Cabinet Chambers, Basinghall Street, Leeds, with a committee of inspection.

THE partnership hitherto subsisting between Messrs. D. John and H. Owen, carrying on business as engineers and smiths, at the Arches, Quay Parade, Swansea, under the style of The North Dock Engineering Works, has been dissolved.

THE shareholders of the Cessnock Repairing Company, Limited, engineers, etc., Govan, Glasgow, have resolved that the company be wound up voluntarily and that Mr. John Heggie Steven, C.A., 82, Gordon Street, Glasgow, be appointed liquidator.

A CONTRACT for ten 10-wheeled passenger locomotives, required for the South Manchuria Railway, has been equally divided between Messrs. Beyer, Peacock & Company, Limited, of the Gorton Foundry, Manchester, and the American Locomotive Company.

THE WELDLESS STEEL TUBE COMPANY, LIMITED, of Rotton Park Street, Birmingham, and Wednesfield, propose shortly to start manufacturing their own steel blooms. The necessary plant is to be erected on the site of the Coalite Works at Wednesfield.

A RECEIVING order and an order of adjudication on the debtor's own petition, has been made against William Lewis Shakespeare, 38, Shrewsbury Road, and Fornham Works, Suffolk Road, Sheffield, pattern maker and engineer trading as Shakespeare, Belt and Company.

THE EFFINGHAM WORKS Rotherham, of Yates, Haywood & Company, and the Rotherham Foundry Company, Limited, were offered for sale by public auction, recently, as a going concern. There was a fair attendance, but no bid for the property, which was eventually withdrawn.

MR. G. F. WEST has resigned his position as managing director of James H. Tozer & Son, Limited, of Birkenhead and London, and has commenced business on his own account at Caxton House, Westminster, London, S.W., under the style of George F. West & Company, engineers and contractors.

THE estates of Hamilton & Company, engineers, 230, Berkeley Street, Glasgow, have in virtue of and for the purposes of the Cessio Acts, been transferred to Mr. H. M. Steele, 190, West George Street, Glasgow, as trustee. Creditors must lodge their claims on or before November 28. The creditors meet on December 20.

MR. A. CATTELL is severing his connection with Moses Eadon & Sons, Limited, of Sheffield, and is joining Mr. Samuel Warren, steel manufacturer, Soho Street, Sheffield, whose business is being formed into a limited liability company under the title of Samuel Warren, Limited. Mr. Warren and Mr. Cattell will be the two first directors.

THE engineering works formerly in the occupation of Henry Williams, Limited, Cathcart, Glasgow, have been acquired by Messrs. G. & J. Weir, Limited, whose Holm Foundry they adjoin. It is proposed to put the necessary alterations in hand immediately, as additional floor space is sorely needed, and the land recently acquired is the only direction in which the works could be extended.

THE secretary of the Machine Tool and Engineering Association, 104, High Holborn, W.C., has issued a notice to the effect that the Association has been registered as a limited company. Its primary object is to exercise control over the organisation and frequency of exhibitions, and its policy is to promote one in London every three years, and possibly one in the provinces alternately with those in London.

MR. W. W. STRAFFORD, late works manager of the Crane Works, Parkhead, and previously of Easton & Andersons, has commenced business on his own account at 165, Liverpool Great Road, Crosby, Liverpool, and has been awarded by the Corrosion Committee of the Institute of Metals the contract for the design and supply of the experimental condensing plant to be used in connection with the researches into the causes of the corrosion of condenser tubes.

THE works at Briton Ferry, Glam., of the Briton Ferry Works, Limited, have been closed down in consequence, it is stated, of the dumping of foreign material into this country. This step was foreshadowed a month or so ago, when the management, after carefully considering the commercial situation, determined that the only course open to them was to give the men notice. The company make hematite pig-iron, and have two furnaces with a capacity of 700 tons per week each furnace.

MR. F. W. PAUL, a British expert, who recently arrived at Sydney under a special engagement by the New South Wales Government, has been appointed Royal Commissioner to report as to the suitability of Australian ores for the manufacture of iron and steel, the cost at which the various sections of iron and steel required by the Government can be produced, whether the existing arrangement with Messrs. Hoskins, local manufacturers, is beneficial to the public interest, and the approximate cost of plant capable of producing the iron and steel likely to be required in future by the various State Governments and the Commonwealth.

ON August 1 meetings were held in London of the creditors and contributories in the liquidation of J. G. Childs & Company, Limited, engineers, of Willesden Green, N.W., under a winding-up order made on May 30 last. A statement of the company's affairs showed unsecured liabilities amounting to £20,640 and assets valued at £3,410. The receiver appointed on behalf of a debenture-holder, whose claim amounted to £5,000, had estimated the assets to realise £2,000 or £2,500, and it does not appear likely, according to the statement of the Senior Assistant Official Receiver, that the unsecured creditors will receive any dividend. The creditors resolved that the liquidation should be left in the hands of the Official Receiver, and the contributories' meeting was formally adjourned, there being no quorum present.

AT an extraordinary general meeting of the Wilsons & Union Tube Company, Limited, held at Glasgow on August 14, the provisional agreement for the sale of the company's business to a new company which is to take over the principal tube making concerns in Scotland, with the exception of Stewarts & Lloyds, Limited, was adopted. The new company will be

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COLONIES, AND FOREIGN GOVERNMENTS.

THE Cupola.
Evans's Rapid.

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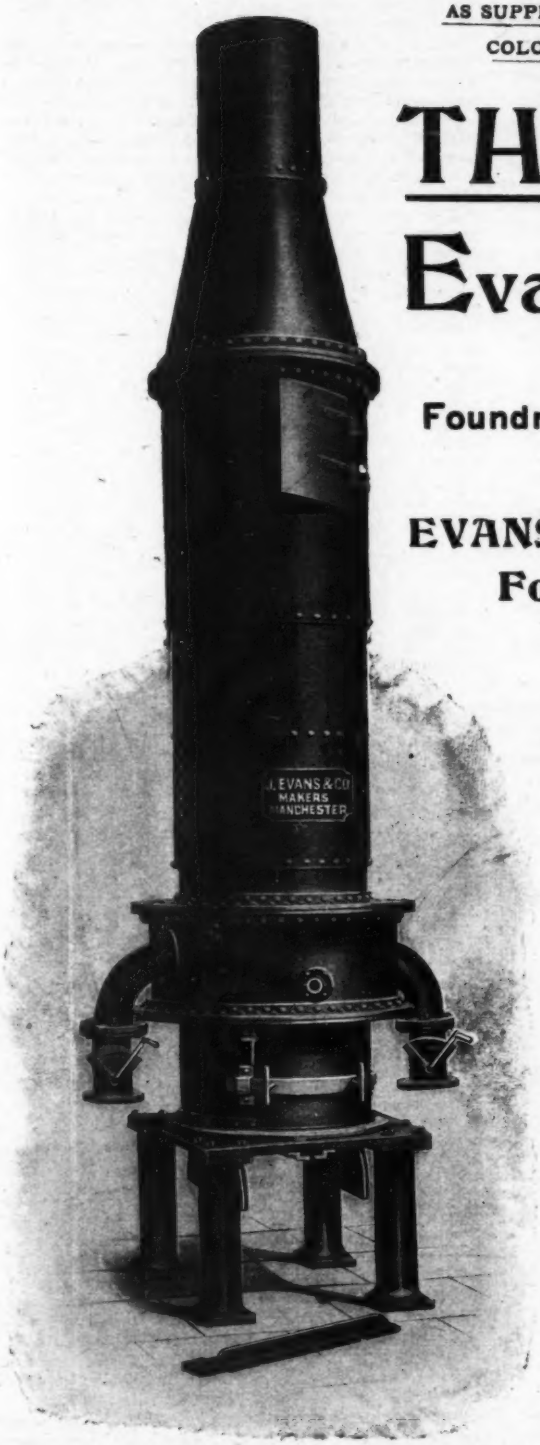
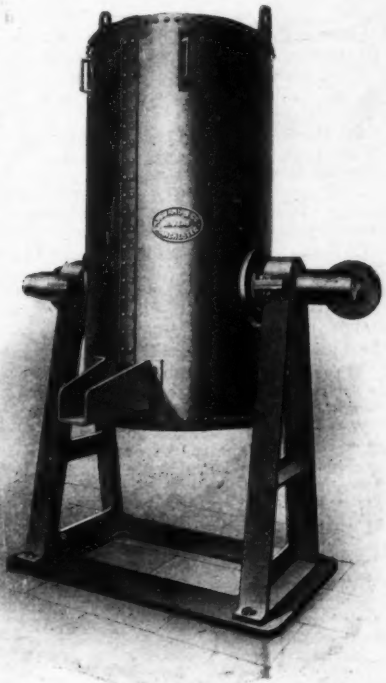
For Emergency Work.





James Evans & Co.,
Britannia Works,
Blackfriars,
MANCHESTER.

Telegrams: "LADLES, MANCHESTER."

known as the Scottish Tubemakers, Limited. According to the circular issued, the business will be taken over as from the 22nd inst. Messrs. Stewarts & Lloyds, Limited, although not a party to the agreement, have agreed to take a substantial interest in the new company, and will be represented on the directorate by Mr. T. C. Stewart. At an extraordinary meeting of David Richmond & Company, Limited, held at Glasgow, the provisional agreement entered into with the other Scottish tube makers for the amalgamation of their businesses, was unanimously adopted.

Mr. Arthur W. Richards, for twenty-five years with Messrs. Bolckow, Vaughan & Company, Limited, of Middlesbrough, and for the last six years as general works manager, has opened offices at Army and Navy Mansions, 109, Victoria Street, Westminster, London, S.W., as a consulting engineer on iron and steel practice and metallurgist. Mr. Richards has had exceptional experience in the manufacture of iron and steel, having visited the most important works on the Continent and in the United States. The various installations and improvements put down under his management for Messrs. Bolckow, Vaughan & Company have been most successful, and include the reconstruction of the blast furnaces, the installation of mixed-pressure turbines for power purposes, turbo blowing plant, remodelling of the open-hearth plant, including charging appliances, besides other important alterations at the rolling mills and Bessemer plant. Mr. Richards has already been engaged as consultant to works abroad.

New Companies.

Aston Cross Foundry, Limited.—Capital £500, in £1 shares, to carry on the business of founders, etc.

J. F. Phillips & Son, Limited.—Capital £15,000, in £1 shares (7,500 preference), to carry on the business of engineers, etc.

W. C. Tackley & Company, Limited.—Capital £500 in £1 shares, to carry on the business of electrical and mechanical engineers, etc.

J. & S. Eyres, Limited.—Capital £12,000, in £1 shares, to carry on the business of ironfounders at Lord Street, Miles Platting, Manchester.

Charles Taylor (Birmingham), Limited.—Capital £35,000 in £1 shares (10,000 preference), to carry on the business of machine tool makers, etc.

George Clark, Junior & Company, Limited.—Capital £10,000 in £1 shares (2,500 preference), to carry on the business of coppersmiths, engineers, etc.

Briventions, Limited.—Capital, £100 in 1s shares, to carry on the business of founders, engineers, etc. Registered office: 21, St. Helen's Place, E.C.

Flynn Manufacturing Company, Limited.—Capital, £1,000, in £1 shares, to carry on the business of machinery and plant manufacturers, insulators of wire, etc.

F. V. Lister & Company, Limited.—Capital £1,000 in £1 shares, to carry on the business of engineers, etc. Registered office: 294, Dashwood House, New Broad Street, E.C.

Summers & Sons, Limited.—Capital £4,000 in £1 shares, to carry on the business of engineers as formerly carried on by A. G., A. W., and A. E. Summers at Wellingborough.

M. H. Denton (Sheffield), Limited.—Capital £10,000 in £1 shares, to carry on the business of steel manufacturers, etc. Registered office: Loxley Works, Wishwood, Sheffield.

Richard Ainsworth & Company, Limited.—Capital, £2,000, in £1 shares, to carry on the business of makers of engine and boiler fittings. Registered office: Audley Works, River Street, Blackburn.

Horsfall & Bickham, Limited.—Capital £30,000, in £1 shares, to take over the business of a wire drawer and engineer, carried on at Bridgwater Works, Pendleton, Manchester, as Horsfall & Bickham.

Webb's Wheel and Engineering Company, Limited.—Capital £2,000, in £1 shares, to take over the business of wire wheel maker and engineer carried on by G. Webb at Priory Street, Monmouth.

Defries, Limited.—Capital £30,000 in 25,000 7 per cent. preference shares of £1 each, and 100,000 ordinary shares of 1s. each, to carry on the business of founders in iron, steel, copper and other metals and alloys.

R. & J. Evans & Company, Limited.—Capital £10,000 in £50 shares, to carry on the business of shipbuilders, founders, engineers, boilermakers, etc., and to acquire the business of R. & J. Evans & Company, Limited (in liquidation).

Psimenos Syndicate, Limited.—Capital £20,000, in £1 shares, to acquire and turn to account iron and chrome ore, magnesite, manganese, copper, and other mines, in any part of the world, and to adopt an agreement with G. J. Psimenos.

Samuel Warren, Limited.—Capital, £10,000 in £1 shares, to take over the business carried on by S. Warren at Soho Street, Sheffield, and to carry on the business of iron and steel manufacturers, converters, founders, etc. Registered office: Soho Street, Sheffield.

Boardite, Limited.—Capital £20,000 in 19,000 7½ per cent. cumulative preference shares of £1 each, and 20,000 ordinary shares of 1s. each, to carry on the business of manufacturers of boardite, engineers, etc. Registered office: Queen Anne's Chambers, Westminster, London, S.W.

Charles A. Gardiner, Limited.—Capital £3,000, in £1 shares, to carry on the business of art metal workers, iron, brass, tin, and copper founders and smiths, etc., to acquire the business carried on by Charles A. Gardiner, at the Ivor Art Metal Works, 8½, The Parade, Birmingham. Registered office: 8½, The Parade, Birmingham.

W. J. Davies & Sons, Limited.—Capital, £26,600, in 2,800 preference shares of £10 each and 600 ordinary shares of £1 each to acquire the business of manufacturers of emery, emery cloth and paper, glass paper and cloth, etc., carried on at 109, Weston-street, Bermondsey, as W. J. Davies and Sons. Office: 109, Weston Street, Bermondsey.

Limited Partnership.—Lambert, Burnley & Company, ironfounders, Eastbrook Foundry, Ernest Street, Diamond Street, Bradford. Registered July 29, partnership for seven years, from August 1, 1911. General partners, H. Burnley, 69, New Cross Street, Bradford; and F. Lambert, 285, Manchester Road, Bradford. Limited partner, E. Smethurst, 239, High Street, Horton, Bradford, contributing £250 in cash.

National Gas Engine Company, Limited.—Capital £1,000,000 in £1 shares (400,000 5 per cent. cumulative preference) to carry on the business of gas and oil engine, electric and gas works plant manufacturers, engineers, etc., and to acquire the business carried on at Ashton-under-Lyne and elsewhere as the National Gas Engine Company, Limited. Registered Office: Wellington Works, Wellington Road, Ashton-under-Lyne.

CHROMAX BRONZE.—This is an alloy of chromium, copper and nickel, which is claimed to be the only copper alloy which contains chromium, and is protected by patents. As chrome-nickel steel is recognised as the best steel, so this bronze is claimed to be superior to any other. As a bearing metal it is said to be unrivalled, and it has a high fusing point of 1,200 degrees F. It is stated that it will not fuse nor cut even if raised to red heat by friction, and will stand 20,000 lbs. pressure per square inch on a 6-in. bearing surface at slow speed. The alloy has a tensile strength of 79,000 lbs. per square inch with an elongation of 3.3 per cent., and is extremely dense. It is acid proof, non-corrosive, is not affected by sea-water, and can be rolled into sheets and wire.

PURE METALS

and ALLOYS. FREE from CARBON.

TITANIUM THERMIT

for

SOUND, STRONG, CLOSE-GRAINED CASTINGS.

Also FERRO VANADIUM and FERRO TITANIUM.

Full Particulars and PRICES from—

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Telegrams: "Fulmen, London."
Telephone: 3749 Central,

27, Martins Lane,
Cannon Street, E.C.

Works: 210a, Bow Road, E.

ELDERS FOUNDRY COKE

AS SUPPLIED TO THE BRITISH ADMIRALTY DOCKYARDS.

The following, selected from numerous letters, are eminent testimony as to the quality of our celebrated "A.A.A." Coppee Foundry Coke, carefully selected, and despatched in sheeted wagons.

From PECKETT & SONS, Bristol.

Bristol, October 25th, 1904.

We have been using your Selected Foundry Coke for some considerable time.
We have pleasure in stating that we are very pleased with it, as we find we get sounder and cleaner castings, more free from blowholes and other defects, than we formerly did.

From BOW, McLACHLAN & CO., LTD. (Paisley Foundry), Paisley, Glasgow.

Paisley, 12th March, 1909.

We have yours of 4th inst., and in reply have pleasure in stating that we have been using your Foundry Coke for several years for special purposes with highly satisfactory results.

Elders Collieries, Ltd., Cardiff.

Personal.

Mr. W. S. Vaughan has been elected a director of Walter Scott, Limited, Leeds.

Sir George B. Hingley has been appointed a Deputy-Lieutenant for Worcestershire.

The late Mr. J. Harrison, of St. Anne's-on-Sea, left estate valued at £3,393 gross.

The late Mr. J. Brown, brassfounder, of Wakefield, left estate valued at £8,953 gross.

Mr. J. A. Kenrick, of Archibald Kenrick & Sons, Limited, will be the Mayor of West Bromwich next year.

The late Mr. W. O. Smith, of McDowall, Steven & Company, Limited, ironfounders, Glasgow, left estate valued at £2,891.

Mr. Malcolm Dillon has retired from the board of Robert Stephenson & Company, Limited, and has been succeeded by Mr. Alexander Cameron.

Mr. E. Le Q. Herbert has been appointed general manager of the works of the Callendar Iron Company, of the Callendar Iron Works, Falkirk.

The late Mr. T. G. Locker, managing-director of Chas. Clifford & Sons, Limited, left estate of the gross value of £1,506, with net personalty £703.

Mr. G. H. Snowball, of Gateshead, firebrick manufacturer, left estate of the gross value of £14,752, of which the net personalty has been sworn at £6,459.

The late Mr. William Douglas, of the firm of Messrs. William Douglas & Sons, Limited, engineers and founders, of Putney, S.W., left estate of the gross value of £5,527 18s. 5d.

Mr. A. J. Hobson, J.P., chairman of William Jessop & Sons, Limited, and a director of R. Hornsby & Company, Limited, will be Lord Mayor of Sheffield for the ensuing year.

A knighthood has been conferred on Lord Provost Archibald M'Innes Shaw, Glasgow, who is the head of the firm of Messrs. Shaw & McInnes, Firhill Iron Works, Spring Bank, Glasgow.

The late Mr. H. B. Jones, senior partner in the firm of G. R. Jones & Company, steel and file manufacturers, Sheffield, left estate of the gross value of £10,930, with net personalty £10,644.

Mr. Douglas G. Cochrane, of Cochrane & Company, Limited, ironfounders, of Ormesby Ironworks, Middlesbrough, has been appointed manager of the Staveley works of the Staveley Coal & Iron Company, Limited, in succession to Mr. F. Gandy, who has resigned.

Mr. Arthur Balfour, managing director of Seebohm and Dieckstahl (Limited), steel manufacturers, Sheffield, has been chosen as the new Master of the Cutlers' Company of Hallamshire. The installation will take place in October. Mr. J. Rossiter Hoyle, the managing director of Messrs. Thos. Firth & Sons, Limited, and Mr. T. W. Ward were elected Senior and Junior Warden respectively in the place of Mr. A. Balfour and Mr. Walter Tyzack, resigned.

The vacancy on the board of William Sugg & Company, Limited, caused by the death of the late Mr. E. Sugg Wright, managing director, has been filled by the selection of Mr. S. E. Thornton, hitherto chairman, as managing director, while Mr. G. H. Matlock, who has spent all his business life with the Company, has been appointed as general manager. Mr. R. W. Kennard, a director of the Company, will be the future Chairman, and Mr. W. S. Brown, formerly secretary, has been elected a director.

Deaths.

Mr. W. Owen, engineer and ironfounder, of the Menai Iron Foundry, Bangor, died recently.

Mr. Benjamin Woodall, ironfounder and fender manufacturer, died recently aged 60. He was formerly the proprietor of the Premier Works, Cromwell Street, Dudley.

Mr. Thomas Russell died on August 14. He was was one of the proprietors of the iron founding business carried on as Walter Macfarlane & Company, at the Saracen Foundry, Glasgow.

Mr. John Tennent, J.P., who died suddenly on August 20, was forty-five years of age, and was chairman and managing director of Messrs. R. B. Tennent, Limited, iron and steel founders, of Whifflet, Coatbridge.

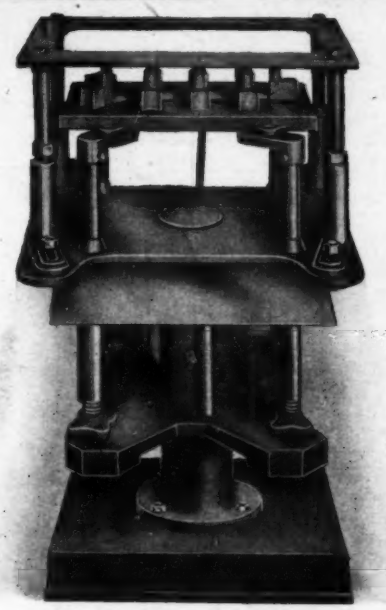
Mr. Henry Martyn Kennard, who died in London, recently, at the age of 78, was one of the original partners of the Falkirk Iron Company, and was also associated with the business of bridge builders formerly carried on as Kennard Brothers, at Crumlin, Mon. This business was acquired by the Blaenavon Company, Limited, a company in which the deceased gentleman retained a large interest.

Mr. F. N. Hobson, Sheriff of Nottingham, died at his residence recently, after an illness lasting several weeks. Mr. Hobson, who was 55 years of age, started his business career as an apprentice to the engineering business of Swift & Wass, Limited, Victoria Works, New Basford, Nottingham, and by his own industry rose until he became a partner in and ultimately sole proprietor of the firm.

The death is announced, at the age of 90, of Mr. Richard Howson, one of the original members of the Iron and Steel Institute. Mr. Howson was for several years constructive engineer to the Newport Ironworks, Middlesbrough, of Messrs. Sir B. Samuelson & Company, Limited, where he designed and erected blast furnaces. Afterwards he was consulting engineer to the firm, and, in conjunction with the late Mr. Samuel Godfrey, he designed and patented a mechanically-revolved puddling furnace. The deceased gentleman read a paper on the Siemens-Martin process at the first meeting of the Iron and Steel Institute in 1869. He was also a member of the Institute of Civil Engineers, and in 1886-7 was President of the Cleveland Institute of Engineers.

GANISTER, CUPOLA BLOCKS, FIRE BRICKS,
FIRE CLAY.
Silica Bricks, Tuyeres, Stoppers, Nozzles, &c.
STEEL MOULDERS' COMPOSITION, SILICA CEMENT.
J. GRAYSON LOWOOD & Co., Ltd.,
DEEPCAR, nr. SHEFFIELD.
Telegrams: "LOWOOD, DEEPCAR."

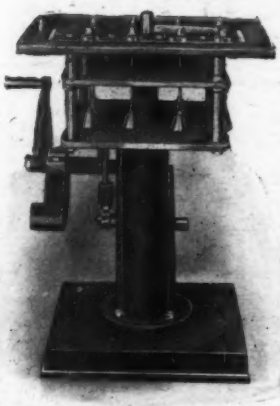
THE MACHINE YOU NEED IN YOUR FOUNDRY.



CLASS "B."
ADAPTABLE TO VARIOUS SIZES OF PATTERN PLATES.

THE "PHOENIX" MOULDING MACHINE.

THE BEST,
THE SIMPLEST,
THE CHEAPEST.



CLASS "A."

Reduces bench Moulding to an accurate Mechanical process.

It eliminates the cost of fettling and fitting inaccurate Castings.

Operated by unskilled labour.

FOUNDRIES COMPLETELY FURNISHED.

CHAS. HALL & Co.,
Newtown Ironworks,
Dixon Street, Dantzic Street,
MANCHESTER.

PRICES OF METALS.

The following table shows the approximate latest prices and position of stocks of metals during the past two years:—

METALS.	End Aug., 1911.	End Aug., 1910.
Iron—Scotch pig warrants ton	*53 0	*56 0
—Middlesbro' warrants ton	46/11	50 1½
—W.C. M/nos Bessemer ... ton	64 0	66 6
—Stock, Scotch ... .. tons	1,000	1,000
Copper—Chili bars, GMB ton	£56 2 6	£56 6 3
—Stock, Europe and afloat tons	66,914	97,506
Tin—English ingots ... ton	£192 10 0	£152 10 0
—Straits ... ... ton	£189 15 0	£153 12 6
—Stock, London, Holland, U.S.A., and afloat ...tons	16,174	18,294
Lead—English pig ... ton	£14 12 6	£12 17 6
Spelter—Ord. Silesian ... ton	£27 15 0	£22 17 6
Quicksilver (75lb)... bottle	£9 0 0	£8 12 6
Antimony—Regulus .. ton	£28 5 0	£28 0 0–£30 0 0

* Settlement price.

CASTINGS.

In the Cleveland district the following are the nominal rates current for castings:—

	£ s. d.		£ s. d.
Columns (plain)	6 10 0	to	6 15 0
Pipes, 1½ to 2½ in.	4 17 6	to	5 2 6
,, 3 to 4 in.	4 10 0	to	5 0 0
,, 5 to 8 in.	4 7 6	to	4 10 0
,, 10 to 16 in.	4 7 6	to	4 10 0
,, 18 to 24 in.	4 7 6	to	4 10 0
Chairs	3 12 6	to	3 15 0
Floor plates (open sand)	2 17 6	to	3 0 0

SCRAP.

The quotations for scrap, subject to market fluctuations, are as follows:—Heavy wrought (mixed), £2 9s. 0d.; light wrought, £1 5s. 0d.; heavy cast, £2 6s. 0d.; all per ton, f.o.b., London. Copper (clean), £51 10s. 0d.; brass (clean), £38 10s. 0d.; lead (usual draft), £13 5s. 0d.; zinc, £21 10s. 0d.; all per ton delivered merchant's yard.

Parliamentary Note.

Dowlais Works Wages.

MR. EDGAR JONES asked the Under-Secretary for India in the Commons, recently, what steps he proposed to take as to the wages paid on Government contracts at the Dowlais Works.

MR. MONTAGU: The Fair Wages Advisory Committee has advised the Secretary of State that the wages paid at Dowlais are, in their opinion, not strictly in conformity with the fair wages resolution. In these circumstances Messrs. Guest, Keen, and Nettlefolds will be informed that no further orders will be placed by the Secretary of State in Council with them at Dowlais until this state of affairs has been remedied.

The same question was put to the Colonial Secretary, who replied in similar terms.

Answering a question by Mr. Keir Hardie, Mr. MCKENNA said the Admiralty adopted the same interpretation of the fair wages resolution as that followed by the India and Colonial Offices. It was open to workmen to claim fair rates for Government contracts at any time, irrespective of the rates of pay which they were receiving for non-Government work. He considered that the non-payment of fair wages generally by a firm was a good ground for the non-retention of the firm on the list of Admiralty contractors.

Pulveriser

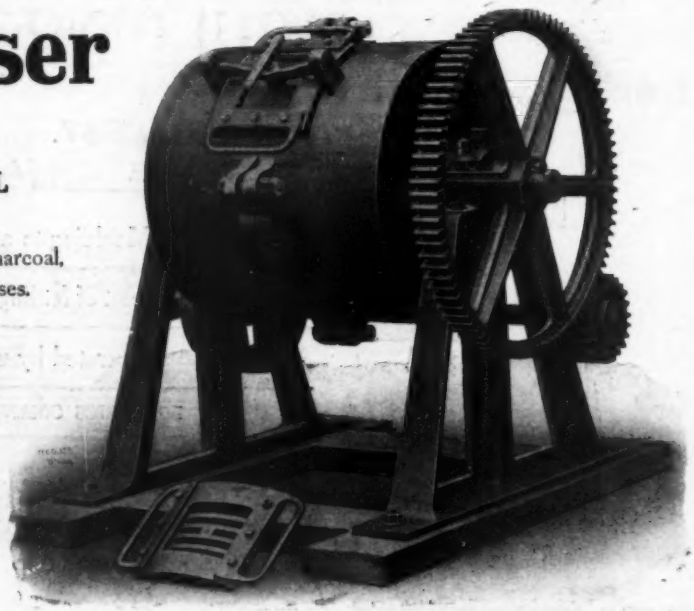
OR

Cylindrical MILL

For grinding Coal Dust Charcoal, &c., for Foundry purposes.

Grinds coal-dust to any degree of fineness—makes smoother castings, and saves time in dressing and fettling.

Illustrated price list on application.



Jones & Attwood, Ltd., Engineers, Stourbridge.

Established 1863.

JAS. DURRANS & SONS,

Phœnix Works, Penistone, Near Sheffield.

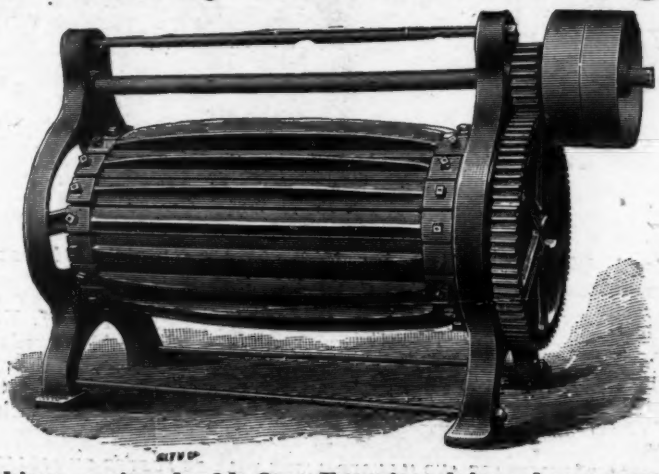
Manufacturers of all

FOUNDRY EQUIPMENTS

COMPOSITION BLACK LEAD, PLUMBAGO, CORE GUM, WHITE DUST & COAL DUST.

Ladles, Cupolas, Fire Bricks, Gannister, Stone Flux, Loam and Sand Mills, Casting Cleaners, Studs, Chaplets, Pipe Nails, Sprigs, Brushes, Wire Brushes, Core Ropes, Bellows, Buckets, Spades, Forks, Riddles, Sieves, Barrows, Etc.

Improved Foundry Rattler or Fettling Drum.



These Machines are invaluable for a Foundry, doing a larger amount of work of a superior quality, in a much shorter time than can be done by hand, without skilled labour.

The following testimonial explains itself :—

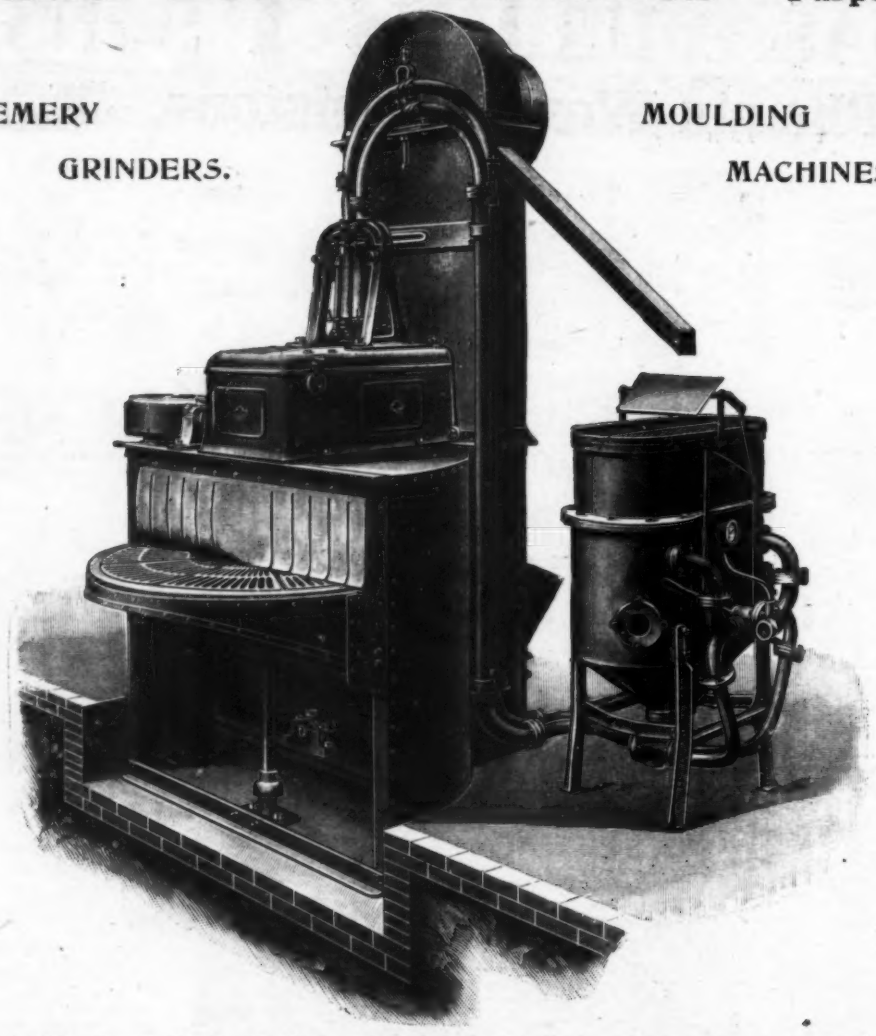
"Dear Sirs,—We have been using your best Blacking for a large number of years, and always use it on our large Ingot Moulds, which, as you know, we have made up to 85 tons in weight.

Yours faithfully, THE BRIGHTSIDE FOUNDRY & ENGINEERING CO., LD."

Sand Blast Machines for all Purposes.

EMERY GRINDERS.

MOULDING MACHINES.



Rotary Table Sand Blast Machines for Malleable, Grey Iron, Brass or Gun Metal Castings.

YOUR CASTINGS WILL BE CLEANED much more EFFECTIVELY, ECONOMICALLY and in less time by our SAND BLAST MACHINES than by the old methods of wire-brushing, rumbling or pickling. The sand blast penetrates and scours the crevices of the most intricate castings; abolishes the chipping or breaking of delicate parts, gives an even colour to the surface, and above all thoroughly removes all the sand adhering to it, thus presenting a face which can be machined much more easily.

FULL PARTICULARS AND ILLUSTRATIONS WILL BE POSTED ON APPLICATION.

The London Emery Works Co., PARK WORKS,

TOTTENHAM, LONDON, N.

THE BUYER'S GUIDE

Addresses and further information will be found by reference to the Firm's Advertisement.

Abrasive Wheels.
Evans, J. & Co.
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Air Compressors.
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Marshall & Co., Horace P.
Phillips, J. W. & C. J.
Thwaites Bros., Ltd.
Tilghman's Patent Sand Blast Co., Ltd.

Air Compressors (Electrically Driven).
Jackman, J. W., & Co., Ltd.
Marshall & Co. Horace P.
Tilghman's Patent Sand Blast Co., Ltd.

Air Compressors (Steam).
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Tilghman's Patent Sand Blast Co., Ltd.

Air Compressors (Belt).
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Tilghman's Patent Sand Blast Co., Ltd.

Annealing.
Evans, J. & Co.
Phillips, J. W. & C. J.

Ash Crushing and Washing Machines.
Evans, J., & Co.
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Phillips, J. W. & C. J.

Barrels (Tumbling).
Alldays & Onions Pneumatic Eng. Co., Ltd.
Evans, J., & Co.
Hall, Charles, & Co.
Jackman, J. W., & Co., Ltd.
London Emery Works Co.
Marshall, H. P., & Co.
Phillips, J. W. & C. J.
Tilghman's Patent Sand Blast Co., Ltd.

Barrows.
F. Braby & Co., Ltd.
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Hall, Charles & Co.
Jackman, J. W., & Co., Ltd.
Olsen, Wm.

Blacklead.
Durrans, J., & Sons.
Evans, J., & Co.
Hall, Charles, & Co.
Jackman, J. W., & Co., Ltd.
Olsen, Wm.
Walker, I. & I.
Wilkinson & Co., Thos., Ltd.

Blowers.
Alldays & Onions Pneumatic Eng. Co., Ltd.
Buffalo Forge Co., Ltd.
Davies, T. & Son.
Dempster, R. & J., Ltd.
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Jackman, J. W., & Co., Ltd.
Keith, James, & Blackman, Co., Ltd.
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Marshall, H. P., & Co., Ltd.
Phillips, J. W. & C. J.
Samuelson & Co., Ltd.
Thwaites Bros., Ltd.

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Ward, T. W., Ltd.

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Jackman, J. W., & Co., Ltd.
London Emery Works Co.

Casting Cleaners.
Durrans, J., & Sons.
Evans, J., & Co.
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Pneumatic Engineering Appliances Co., Ltd.
Tilghman's Patent Sand Blast Co., Ltd.

Cement.
Dyson, J. & J.
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Hall, Charles & Co.
Jackman, J. W., & Co., Ltd.
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Lowood, J. Grayson, & Co., Ltd.
Marshall & Co., Horace P.
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Olsen, Wm.
Plasti-Kton Co.
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Marshall & Co., Horace P.
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Olsen, Wm.
Wilkinson, T. & Co., Ltd.

Charcoal.
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Firminger, J. & Co., Ltd.
Hall, Charles & Co.
Jackman, J. W., & Co., Ltd.
Mansergh, T. E.
Sykes, James.
Walker, I. & I.

Charging Platforms.
Alldays & Onions Pneumatic Eng. Co., Ltd.
Davies, T., & Son.
Evans, J., & Co.
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Thwaites Bros., Ltd.

Coal Dust.
Cumming, Wm., & Co., Ltd.
Durrans, J., & Sons.
Evans, J., & Co.
Hall, Charles & Co
Jackman, J. W., & Co., Ltd.
Mansergh, T. E.
Olsen, Wm.
Sykes, James.
Walker, I. & I.
Wilkinson & Co., Thos., Ltd.
Williams, John (Birmingham Sand) Ltd.

Coke (Foundry).
Elders Navigation Collieries.

Coke Breakers.
Evans, J., & Co.
Jackman, J. W. & Co., Ltd.
Marshall & Co., Horace P.
Phillips, J. W., & C. J.

Core Boxes.
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Jackman, J. W. & Co., Ltd.
Olsen, Wm.

Core Compounds.
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Durrans, J. & Sons.
Evans, J., & Co.
Hall, Charles, & Co.
Jackman, J. W. & Co., Ltd.
Olsen, Wm.
Wilkinson, Thos. & Co.

Core Gums.
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Evans, J., & Co.
Hall, Charles, & Co.
Jackman, J. W. & Co., Ltd.
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Walker, I. & I.
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Marshall, H. P. & Co.
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Hislop, R. & G.
Jackman, J. W. & Co., Ltd.
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Phillips, J. W. & C. J.
Portway, C. & Son.

Core Ropes.
Durrans, J. & Sons.
Evans, J., & Co.
Hall, Charles, & Co.
Jackman, J. W., & Co., Ltd.
Olsen, Wm.
Wilkinson, T. & Co.

Core Vents.
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Hall, Charles & Co.
Jackman, J. W., & Co., Ltd.
Olsen, Wm.

Cranes.
Alldays & Onions Pneumatic Eng. Co., Ltd.
Evans, J. & Co.
Jackman, J. W., & Co., Ltd.
Vaughan & Son, Ltd.
Ward, T. W., Ltd.

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Hall, Charles, & Co.
Olsen, Wm.

Crucible Furnaces.
Alldays & Onions Pneumatic Eng. Co., Ltd.
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Jackman, J. W., & Co., Ltd.

Crucible Furnaces (Lift-out)
Alldays & Onions Pneumatic Eng. Co., Ltd.
Evans, J., & Co.
Jackman, J. W., & Co., Ltd.
Phillips, J. W. & C. J.

Crucible Furnaces (Tilting)
Alldays & Onions Pneumatic Eng. Co., Ltd.
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Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Phillips, J. W. & C. J.

Crushing Mills.
Evans, J., & Co.
Jackman, J. W., & Co., Ltd.

Cupolas.
Alldays & Onions Pneumatic Eng. Co., Ltd.
Davies, T. & Son.
Durrans, J. & Sons.
Evans, J., & Co.
Hall, Charles & Co.
Jackman, J. W. & Co., Ltd.
London Emery Works Co.
Marshall, H. P. & Co.
Phillips, J. W. & C. J.
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Cupola Linings.
Evans, J., & Co.
Hall, Charles & Co.
Harris & Pearson.
Jackman, J. W., & Co., Ltd.
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Emery Grinders.
Alldays & Onions Pneumatic Eng. Co., Ltd.
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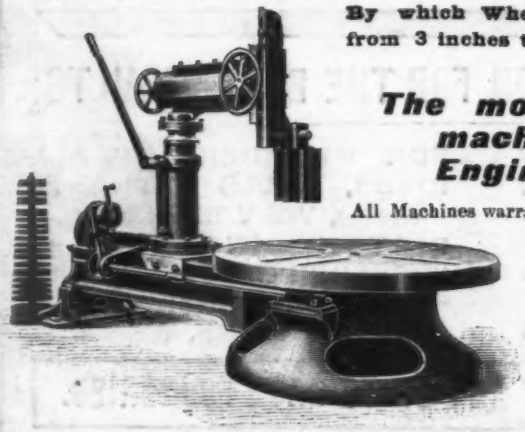

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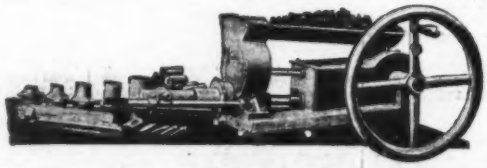

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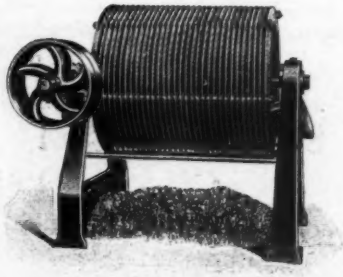

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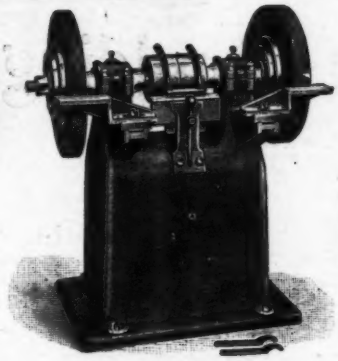

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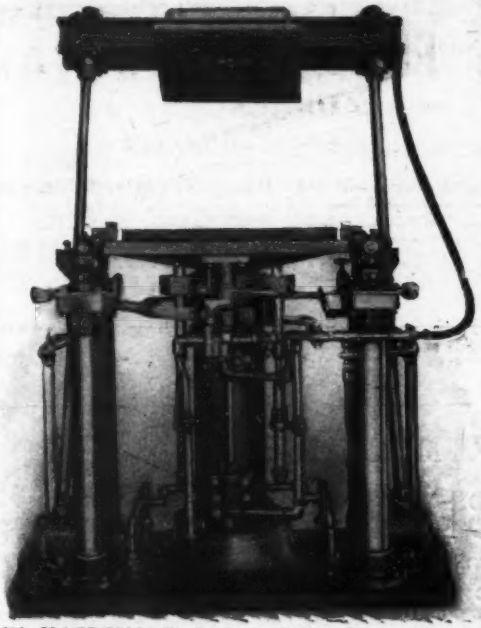

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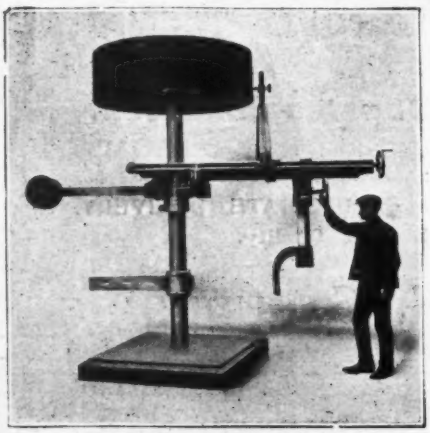

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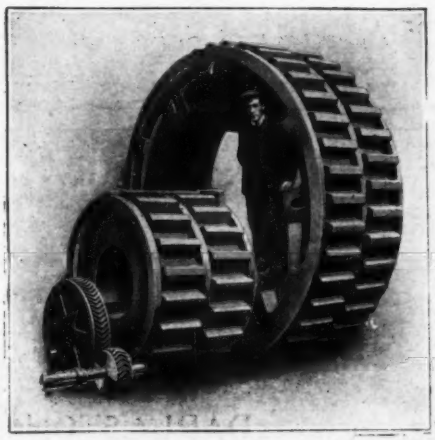

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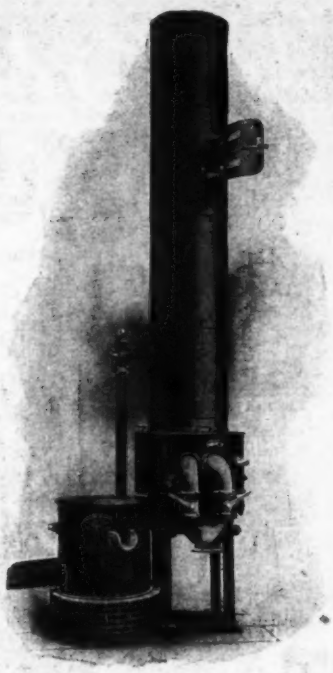

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